MARAIS DES CYGNES RIVER BASIN LAKE PROTECTION PLAN
Water Body: Cedar Creek Lake
Water Quality Issue: Eutrophication

1. INTRODUCTION AND PROBLEM IDENTIFICATION

Subbasin: Marmaton River **Counties:** Bourbon

HUC 8: 10290104 **HUC 11** (HUC14): 010 (070)

Ecoregion: Central Irregular Plains/Wooded Osage Plains (40c)

Drainage Area: Approximately 12.74 square miles (**Figure 1**)

Conservation Pool: Built in 2001
Area = 220 acres
Watershed Area: Lake Surface Area = 37:1
Maximum Depth = 15 meters (50 feet)
Mean Depth = 6 meters (20 feet)
Retention Time = 0.65 years (8 months)

Designated Uses : Primary Contact Recreation (B); Expected Aquatic Life Support; Drinking Water; Industrial Water Supply Use; Food Procurement; Irrigation Use; Livestock Watering Use; Groundwater Recharge

Authority: Marmaton Watershed District

Threatened Use: All uses are threatened to a degree by future eutrophication

Water Quality Standard: Nutrients - Narrative: The introduction of plant nutrients into streams, lakes, or wetlands from artificial sources shall be controlled to prevent the accelerated succession or replacement of aquatic biota or the production of undesirable quantities or kinds of aquatic life (KAR 28-16-28e(c)(2)(A)).

The introduction of plant nutrients into surface waters designated for primary or secondary contact recreational use shall be controlled to prevent the development of objectionable concentrations of algae or algal by-products or nuisance growths of submersed, floating, or emergent aquatic vegetation (KAR 28-16-28e(c)(7)(A)).

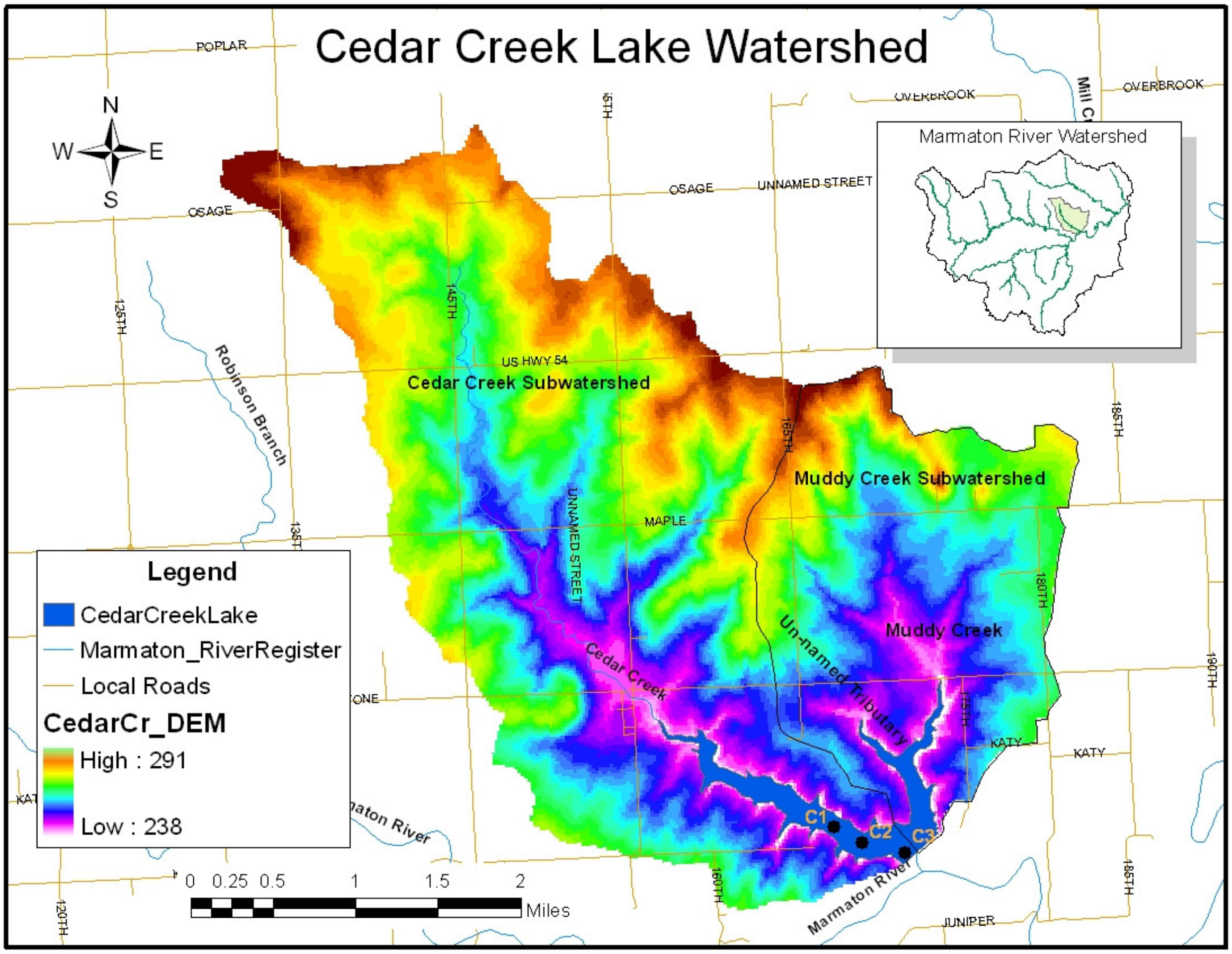

Figure 1. DEM (meter) and water quality sampling sites of Cedar Creek Lake Watershed.

2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

Level of Eutrophication: Trophic State Index = 51 (Slightly Eutrophic) at Site C1
Trophic State Index = 53 (Slightly Eutrophic) at Site C2
Trophic State Index = 48 (Mesotrophic) at Site C3

The Trophic State Index (TSI) is derived from the chlorophyll *a* concentration (Chla). Trophic state assessments of potential algal productivity were made based on Chla, nutrient levels, and values of the Carlson Trophic State Index (TSI). Generally, some degree of eutrophic conditions is seen with Chla over 12 µg/L and hypereutrophy occurs at levels over 30 µg/L. The Carlson TSI derives from the Chla concentrations and scales the trophic state as follows:

1. Oligotrophic TSI < 40
2. Mesotrophic TSI: 40 - 49.99
3. Slightly Eutrophic TSI: 50 - 54.99
4. Fully Eutrophic TSI: 55 - 59.99
5. Very Eutrophic TSI: 60 - 63.99
6. Hypereutrophic TSI: 64

Lake Monitoring Sites: Stations C1, C2, C3 in Cedar Creek Lake [three surveys in 2004, (7/19, 8/2, and 8/18)], and main basin (in the proximity of Site C3) in 2006.

Stream Chemistry Sites: Muddy Creek, 1992 (4/13, 4/16, 4/19, and 4/20)
Cedar Creek, 1992 (4/13, 4/16, 4/19, and 4/20)

Long-Term Hydrologic Conditions: Flow duration curves estimated using Marmaton River near Uniontown (drainage area ~ 84 sq miles; 2001 – 2006) and near Marmaton (drainage area ~ 292 sq miles; 1971 – 2006) are shown in **Figure 2**. Median inflow for Cedar Creek Lake, estimated using Uniontown data (USGS06917240) is 0.76 (1.50 ac-ft) while 10% and 80% exceedance inflow are 12.59 cfs (24.92 ac-ft) and 0 cfs (0 ac-ft), respectively. During the period of 2002 – 2004, annual average total inflow is 5,523 ac-ft, ranging from 3,070 ac-ft in 2003 to 9,158 ac-ft in 2004 (**Figure 3**).

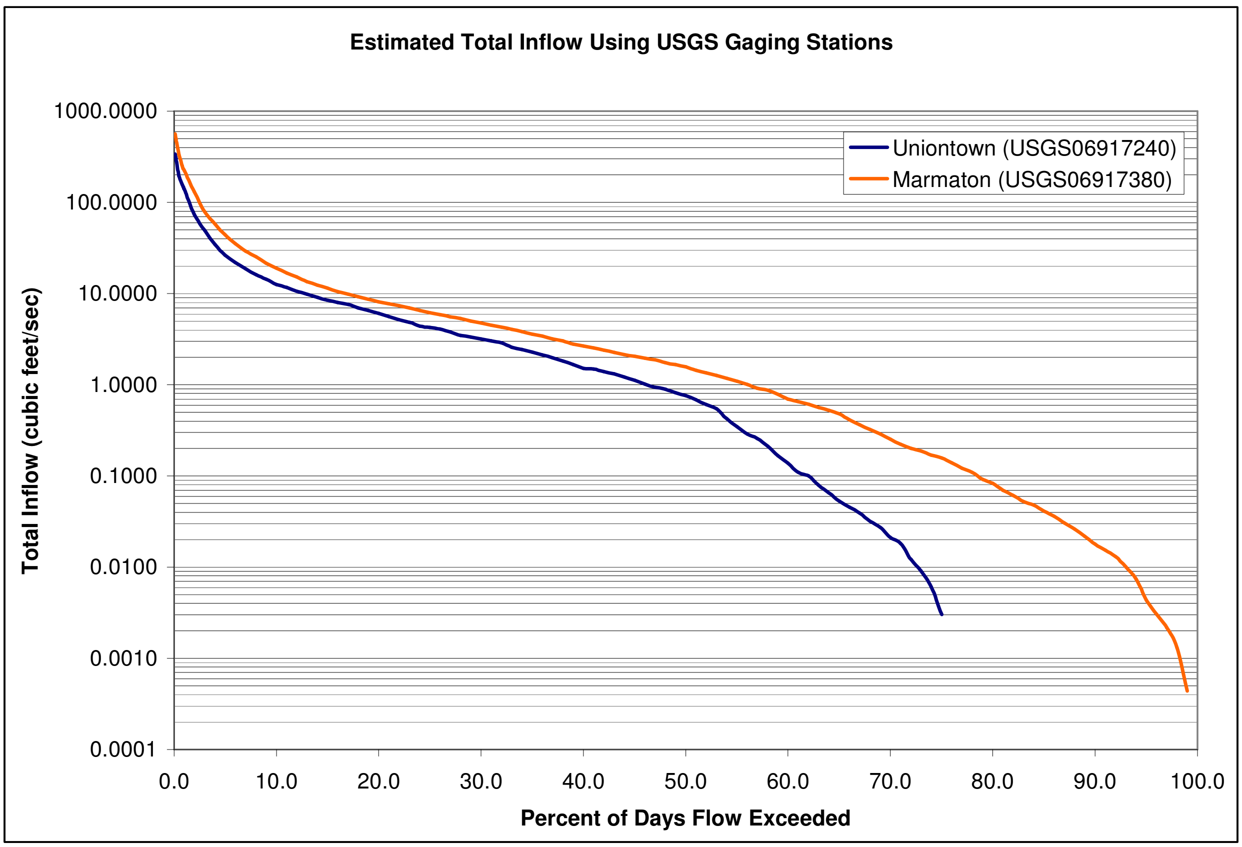

Figure 2. Flow duration curves of total inflow estimated using two USGS gaging stations.

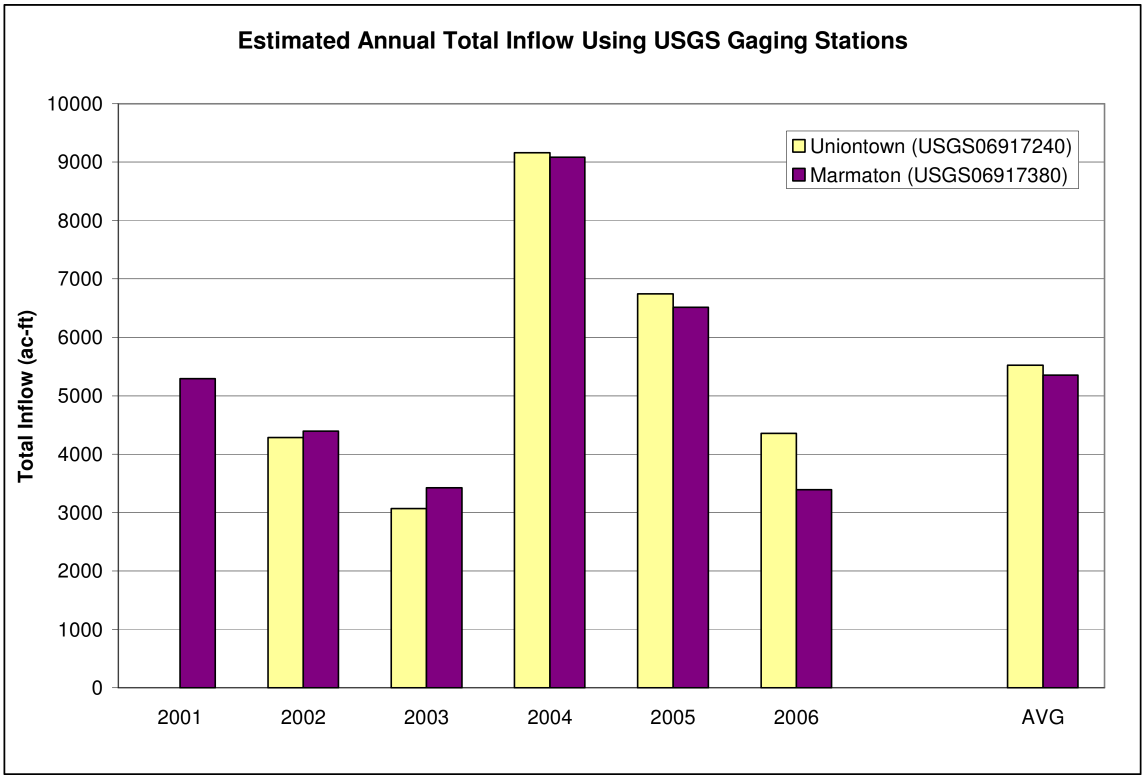

Figure 3. Annual total inflow estimated using two USGS gaging stations during 2001 – 2006.

Current Condition: Cedar Creek Lake had a concentration of 12.0 µg/L of Chla measured near the dam (Site C3) on 8/18/2004, with a corresponding Trophic State Index (TSI) value of 55. On 8/2/2004, the Chla concentration at Site C3 was below the instrument detection limit. **Figure 4** shows the Chla concentrations at the three sampling sites in 2004 and at the Main Basin site during 2006 and 2007. As indicated, Site C2 has the highest Chla concentrations while the lowest Chla concentrations appear at Site C3 (or Main Basin). On 8/18/2004, Chla concentrations were consistently either at or over the Chla goal for Primary Contact Recreation Use (12 µg/L) and Public Water Supply (10 µg/L). On average, Chla concentrations are 8, 10, and 6 µg/L for Sites C1, C2, and C3, respectively.

Total phosphorus (TP) concentrations average 41 µg/L at Site C3, ranging from 29 µg/L on 8/18/2004 to 53 µg/L on 7/19/2004 (**Figure 5**). However, during 2006, the TP level at the main Basin site is below the instrument detection level (0.02 mg/L). Total nitrogen (TN) concentrations average 0.86 mg/L, ranging from 0.78 mg/L on 8/18/1004 to 1.07 mg/L on 7/19/2004. The ratio of TN and TP has been used to determine which of these nutrients is most likely limiting plant growth in Kansas aquatic ecosystems (Dzialowski et al., 2005). Generally, lakes that are N limited have water column TN:TP ratios < 8 (mass); lakes that are co-limited by N and P have water column TN:TP ratios between 9 and 21; and lakes that are P limited have water column TN:TP ratios > 29. For Cedar Creek Lake, TN:TP ratios average 21 at Site C3, ranging from 20 to 27, suggesting that Cedar Creek Lake is a co-limited lake (**Figure 6**). The status of the Cedar Creek Lake's TN:TP ratios is similar to those of Fort Scott City Lake (TN:TP

= 16), Bone Creek Lake (TN:TP = 23), Bourbon Co State Fishing Lake (TN:TP = 13), and Lake Crawford (TN:TP = 13) in the region (Carney, 2003, 2004, 2005, 2006).

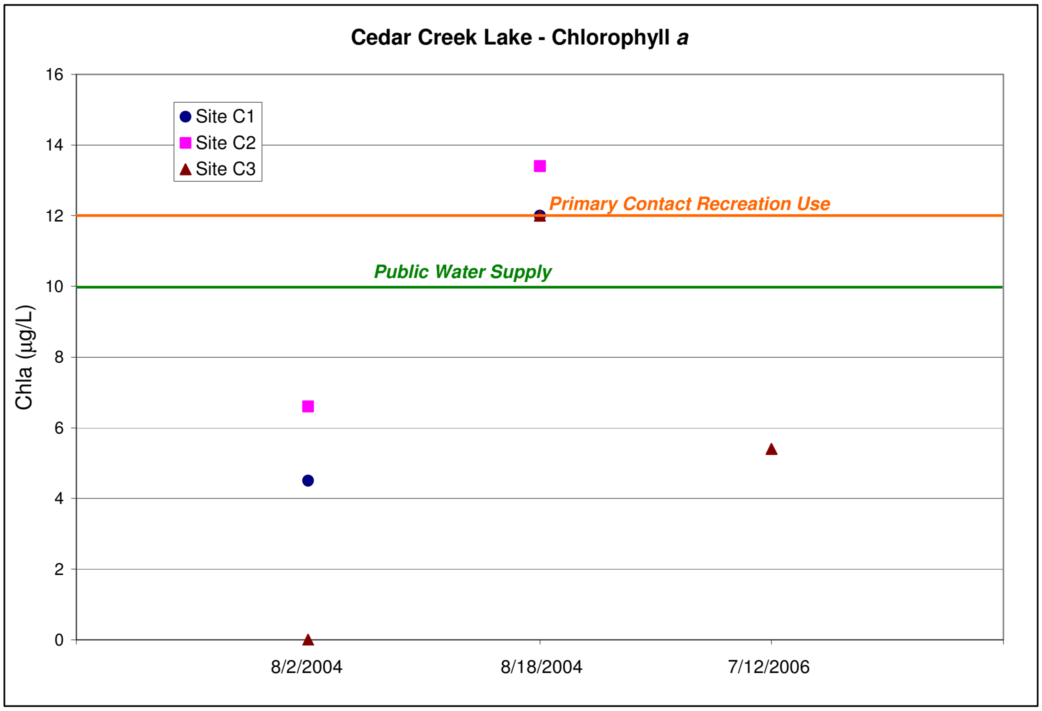

Figure 4. Chla (Chlorophyll *a*) concentrations in Cedar Creek Lake during 2004.

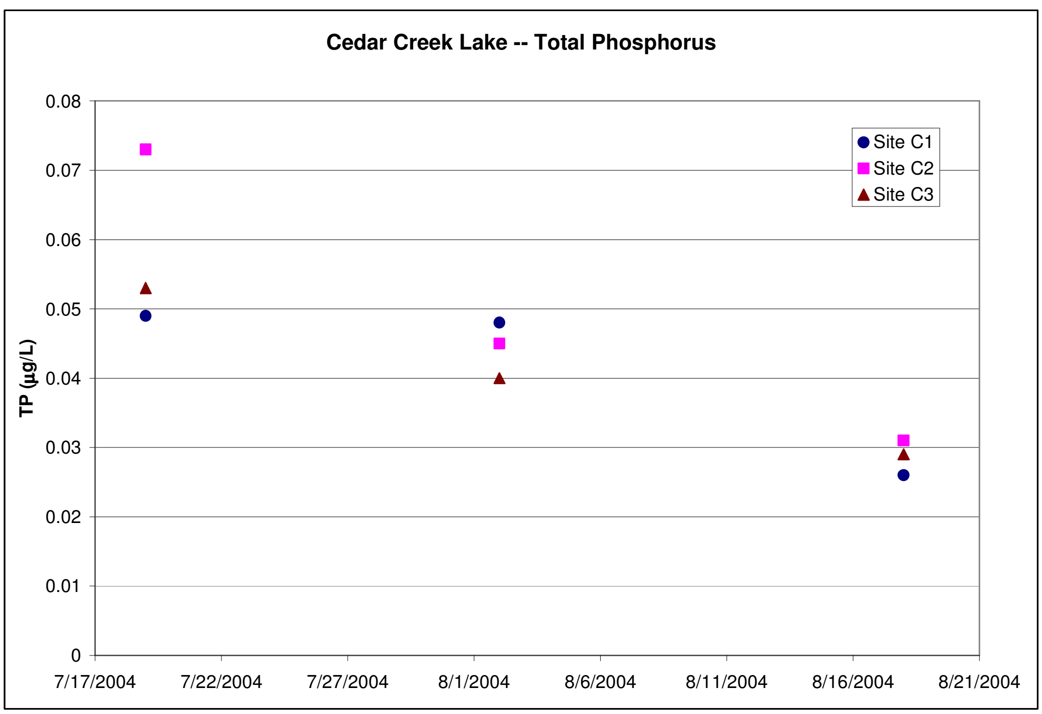

Figure 5. Total phosphorus at Cedar Creek Lake.

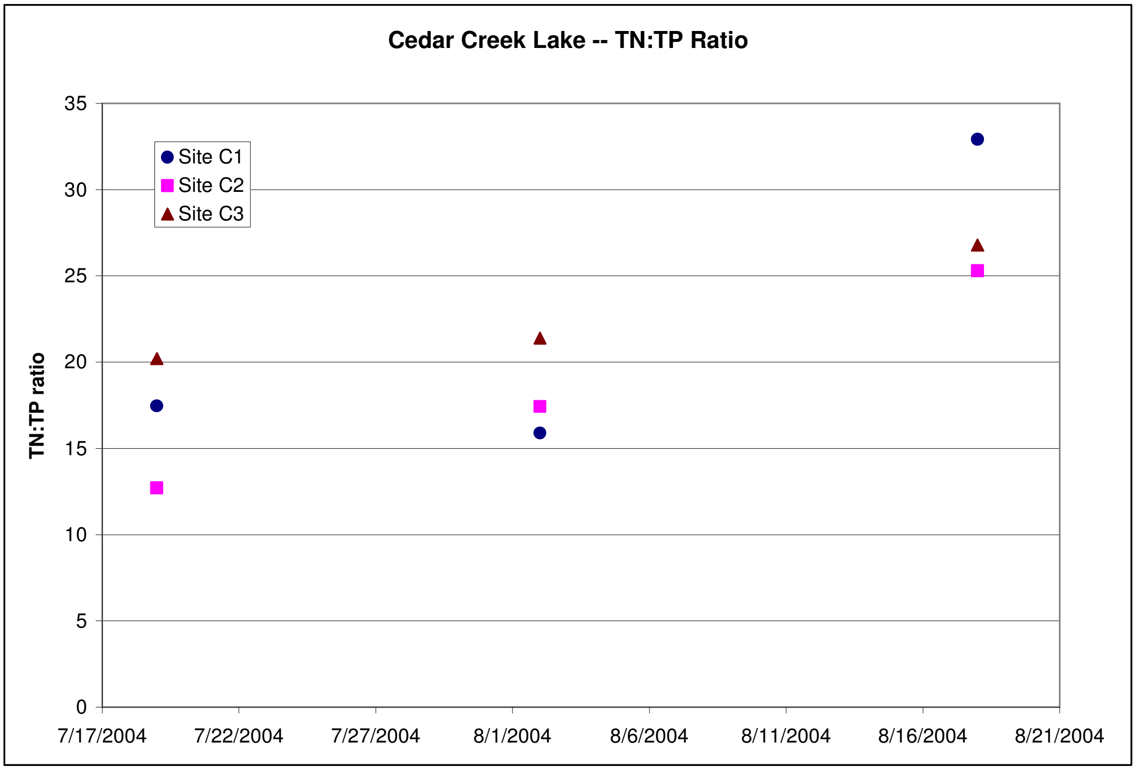

Figure 6. TN:TP ratios at Cedar Creek Lake (TN values were estimated using a TOC-TKN equation derived from the five surrounding lakes (Fort Scot Lake, Lake Crawford, Rock Creek, Bone Creek Lake, and Bourbon County State Fishing Lake).

Figure 7 summarizes the current and possible future trophic conditions of Cedar Creek Lake using a multivariate TSI compassion chart. TSI(Chla) – TSI(TP) is plotted on the vertical axis. Points below TSI(Chla) = TSI(TP) indicate situations where phosphorus may not be limiting Chla where points above TSI(Chla) = TSI(TP) indicate the opposite. TSI(Chla) – TSI(SD) is plotted on the horizontal axis, showing that if the Secchi depth (or SD) is greater than expected from the Chla trophic index, large organic materials dominate by zooplankton grazing. If the Secchi depth is less than expected from the Chla index, transparency is dominated by non-algal factors such as color or inorganic turbidity. Points near or on the diagonal line occur in turbid situations where phosphorus is bound to clay particles and therefore turbidity values are closely associated with phosphorus concentrations (Dip-In, 2007). The average multivariate TSI plot indicates that Cedar Creek Lake has ample phosphorus levels and is slightly limited by non-algal turbidity.

To estimate maximum summer Chla concentrations in Cedar Creek Lake, a statewide regression equation (max Chla = $10^{(1.094*\log(\text{mean Chla})+0.146}$, p<0.001, R^2 = 0.95) was used (Carney, 2003). As calculated, the expected maximum summer Chla concentrations are 14 µg/L at Site C1 whereas the maximum summer Chla concentration is likely 15 µg/L at Site 3, using the average Chla concentration of Sites 1 and Site 2 (5.5 µg/L), instead of 0 µg/L, for 8/2/2004 (**Figure 8**).

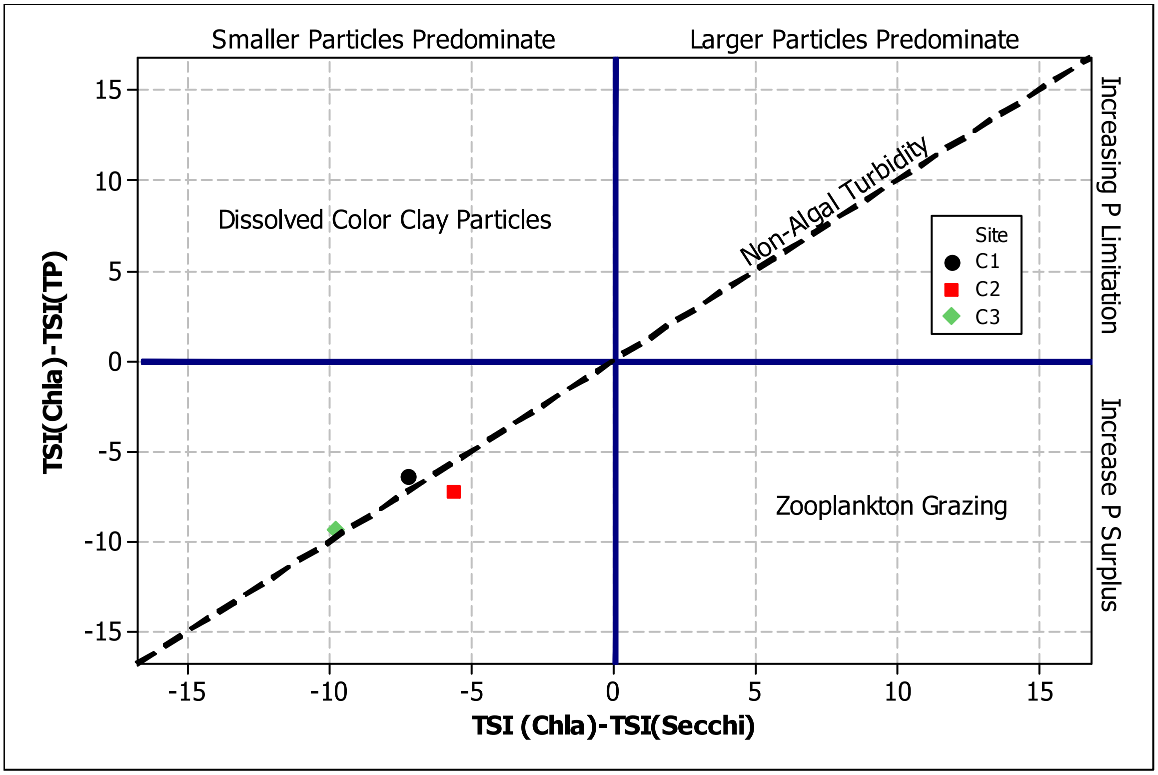

Figure 7. Average multivariate TSI compassion chart of Cedar Creek Lake.

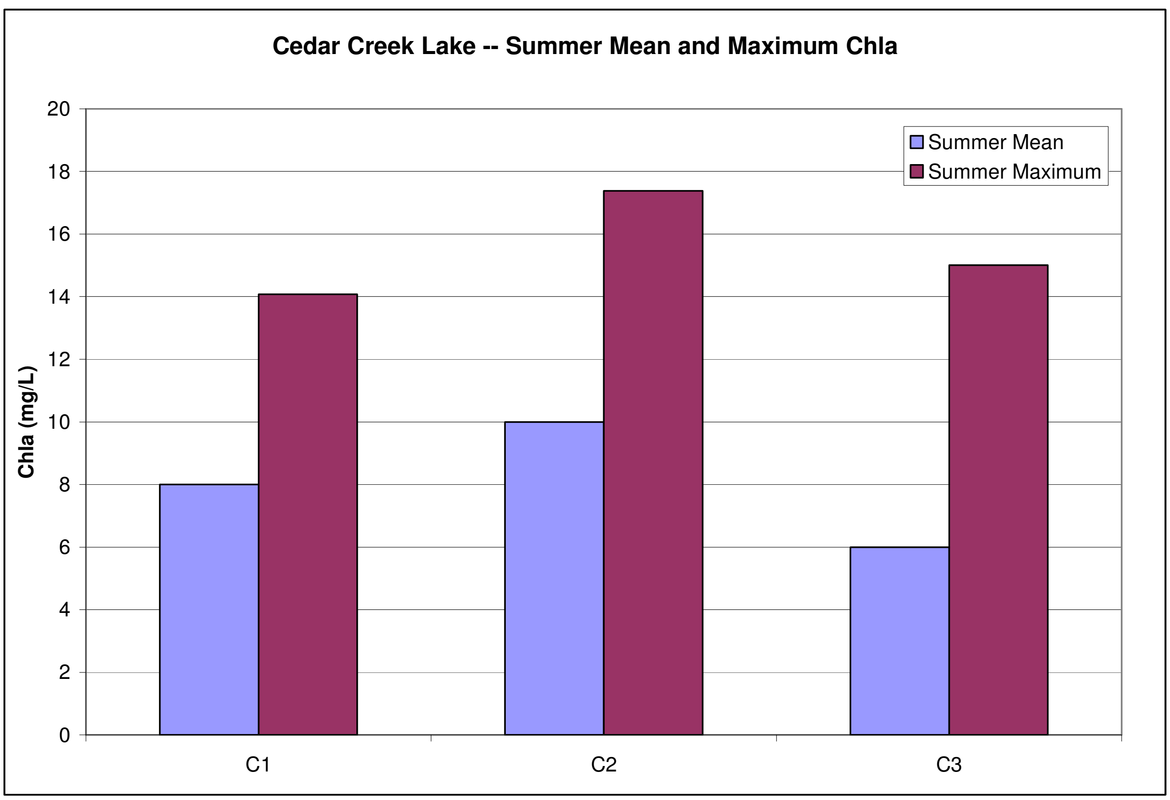

Figure 8. Mean and maximum summer Chla concentrations in Cedar Creek Lake.

Table 1 summarizes average trophic conditions of Cedar Creek Lake in comparison to other lakes and reservoirs in the state and region. As indicated in **Table 1**, Cedar Creek Lake typically has the lower nutrient and Chla values and a higher Secchi depth reading than 19 TMDL lakes surveyed in 2002 and 2003. However, the TN and TP concentrations are greater than the nutrient criteria suggested by EPA Region VII. An index (Chla/TP) was used to evaluate algal use of phosphorus supply (Carney, 2003). There is a limited response by algae to phosphorus if index are values less than 0.13, suggesting that nitrogen, light or other factors may be more important. If values are greater than 0.4, a strong algal response to changes in phosphorus prevails. The range between 0.13 and 0.4 indicates a moderate response by algal to phosphorus levels. For Cedar Creek Lake, Chla/TP index values average 0.14, suggesting that algal communities are moderately controlled by TP.

Table 1. Trophic state of Cedar Creek Lake and its comparisons with other ecoregional, state and regional lakes and reservoirs.

Lake	TN	TP	TN:TP	Chla	Secchi depth	Non-algal turbidity	Chla/TP
	µg/L	µg/L		µg/L	m	1/m	
Cedar Creek Lake (C3)	856	41[4]	21.1	6	1.47	0.54	0.14
Central Irregular Plains[1]	873	66	17.9	17	1.03	0.55	0.46
TMDL lake survey[2]	1,530	146	15.2	33	0.55	0.99	0.32
Kansas[1]	875	72	16.0	19	0.97	0.56	0.45
EPA Region VII[1]	1,685	129	27.8	29	0.88	0.41	0.36
Trophic Criteria[3] (Central Irregular Plains, KS)	362	20	18.0	8	1.30	--	0.40
Trophic Criteria[1] (EPA Region VII)	700	35	20.0	8	--	--	0.23

[1]RTAG – EPA Region VII database (100 - 1000 acres) obtained from the Kansas Biological Survey.
[2]Small – medium size of 19 TMDL lakes surveyed in 2002 and 2003.
[2]Dodds et al (2006), Determining ecoregional reference conditions for nutrient, Secchi depth and chlorophyll *a* in Kansas lakes and reservoirs.
[4]Values were derived, based on 2004 data.

Desired Endpoint for Cedar Creek Lake in 2012 – 2014:

The final TMDL will correspond with the state goal of achieving an average Chla concentration of 10 µg/L or less. The desired endpoint will maintain the trophic condition of the lake at or below its current summer chlorophyll *a* concentration (below 10 µg/L) since the lake serves as a future Public Water Supply.

3. SOURCE INVENTORY AND ASSESSMENT

Land Use: The predominant land use in the Cedar Creek Lake Watershed is pasture (48%), followed by cultivated cropland (terraced, 7%; non-terraced 6%), according to the local land use/land cover data from NRCS Bourbon County Conservation District (written comm., Schoenberger, 2007). Together, they account for about 62% of the total land area in the watershed. Approximately 6% of the watershed is occupied by woodland, whereas 6% is grazed rangeland. Farmstead and built-up areas comprise 3% of the watershed (**Figure 9**). A detailed land use/land cover summary is shown in **Table 2**.

NPDES and Livestock Waste Management Systems: There is no NPDES facility identified in the Cedar Creek Watershed. However, there are two confined animal feedlot operations (CAFOs), which are located each in the north and south boundary of the watershed (**Figure 9**). The total animal number for these two livestock facilities is about 50 cattle (40 head on the north site and 10 head on the south site).

Since about 6% of the land is grazed rangeland, the grazing density of livestock is small in summer and moderate in winter. According to the National Agricultural Statistics Service, the number of unconfined cattle surveyed for Bourbon County averages 55,571 head (median, 56,000 head) during 1990-2006. Based on the proportional rangeland area to Bourbon County, the number of unconfined cattle in the Cedar Creek Watershed average 71 head, ranging from 62 to 79. As shown in **Figure 10**, total unconfined cattle in the Cedar Creek Watershed increases over time, indicating that animal waste may be a potential pollution source to Cedar Creek Lake.

On-Site Waste Systems: The population density for the Cedar Creek Lake Watershed is 24 people per square mile (total population, 309), which is identical to the density of Bourbon County, based on 2000 US Census Data. The rural population projection for Bourbon County through 2020 is 12%. Based on average family size of 2.97 people in the county, there are about 104 septic tank systems in the watershed. Though the failing rate of the septic systems in the county is 0.93% (National Environmental Service Center, 1998), the failing rate is approximately 50% for the watershed because of high clay content of the soils according to NRCS Bourbon County Conservation District (personal comm., Schoenberger). Thus, failing septic systems are likely an important source of nutrients to the lake.

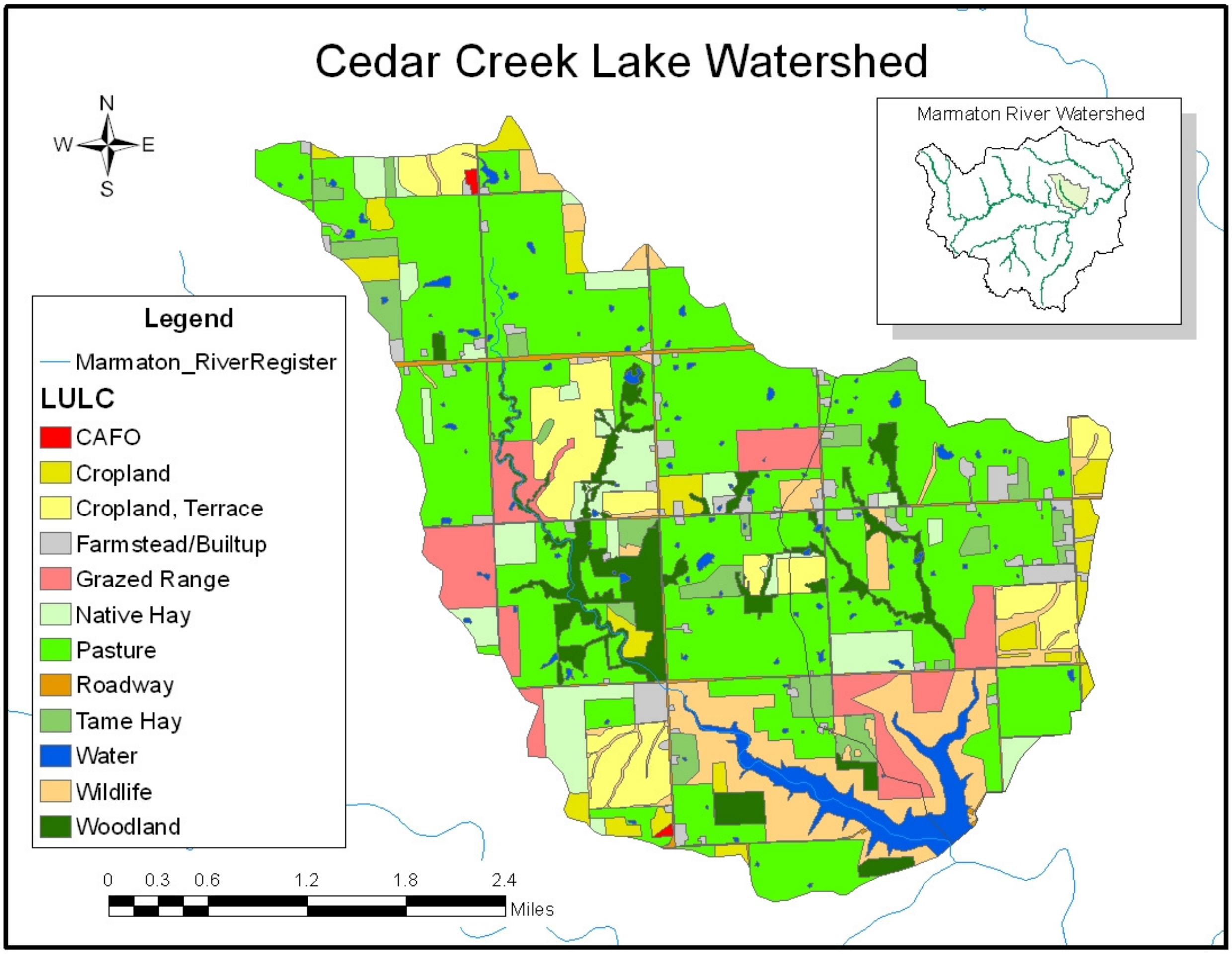

Figure 9. Land use and land cover map of the Cedar Creek Lake Watershed.

Table 2. Watershed land use/land cover summary.

Land Use/Land Cover	Cedar Creek Watershed		Muddy Creek Watershed		Whole Watershed
	-- acre --	-- % --	-- acre --	-- % --	-- acre --
CAFO	9	0			9
Cropland	200	3	98	4	298
Cropland, Terrace	448	8	139	6	587
Grazed Range	346	6	179	7	525
Native Hay	410	7	116	5	526
Pasture	2,800	49	1,164	47	3,965
Roadway	102	2	44	2	146
Tame Hay	227	4	112	5	339
Farmstead/Built-up	134	2	107	4	240
Water	208	4	94	4	302
Wildlife	438	8	318	13	756
Woodland	408	7	99	4	508
Total	*5,731*		*2,469*		*8,201*

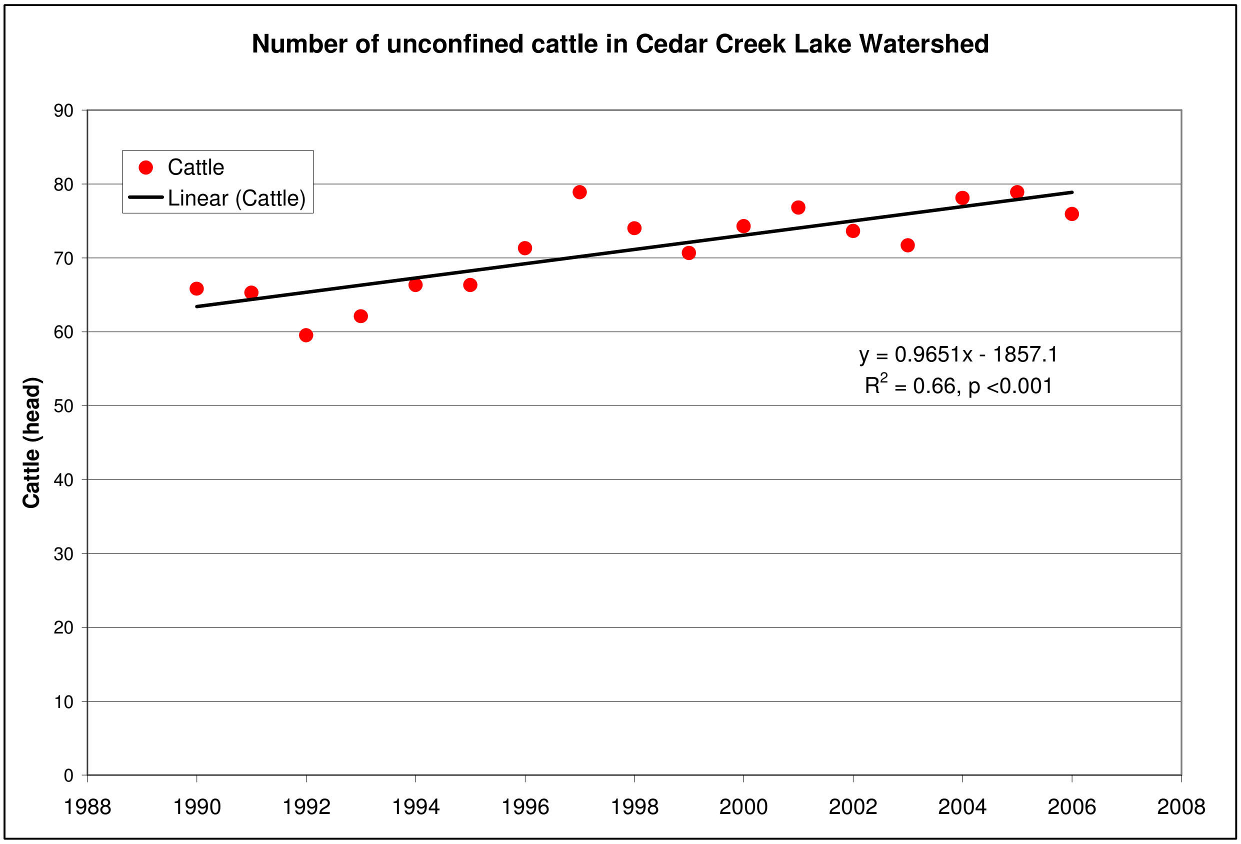

Figure 10. Unconfined cattle distribution in the Cedar Creek Lake Watershed.

Contributing Runoff: **Figure 11** shows soil permeability values across the watershed, based on NRCS STATSGO database. The watershed-wide soil permeability averages 0.62"/hr. According to an USGS open-file report (Juracek, 2000), the threshold soil-permeability values that represent very high, high, moderate, low, very low, and extremely low rainfall intensity, were set at 3.43, 2.86, 2.29, 1.71, 1.14, and 0.57"/hr, respectively. The lower rainfall intensities generally occur more frequently than the higher rainfall intensities. The higher soil-permeability thresholds require a more intense storm so that areas with higher soil permeability potentially may contribute runoff. Runoff is chiefly generated as infiltration excess with rainfall intensities greater than soil permeabilities. As soil profiles become saturated, excess overland flow is produced.

For the Cedar Creek Lake Watershed, all of the land has soil permeability values less than 1.30"/hr consistent with high clay content of soils in the watershed. Under the very low (1.14"/hr) runoff condition, the potential contributing area is about 75%. Storms that produce 0.57"/hr of rain will generate runoff from 60% of the watershed area, which is dominated by pasture (**Figure 9**) and cultivated cropland (**Figure 11**).

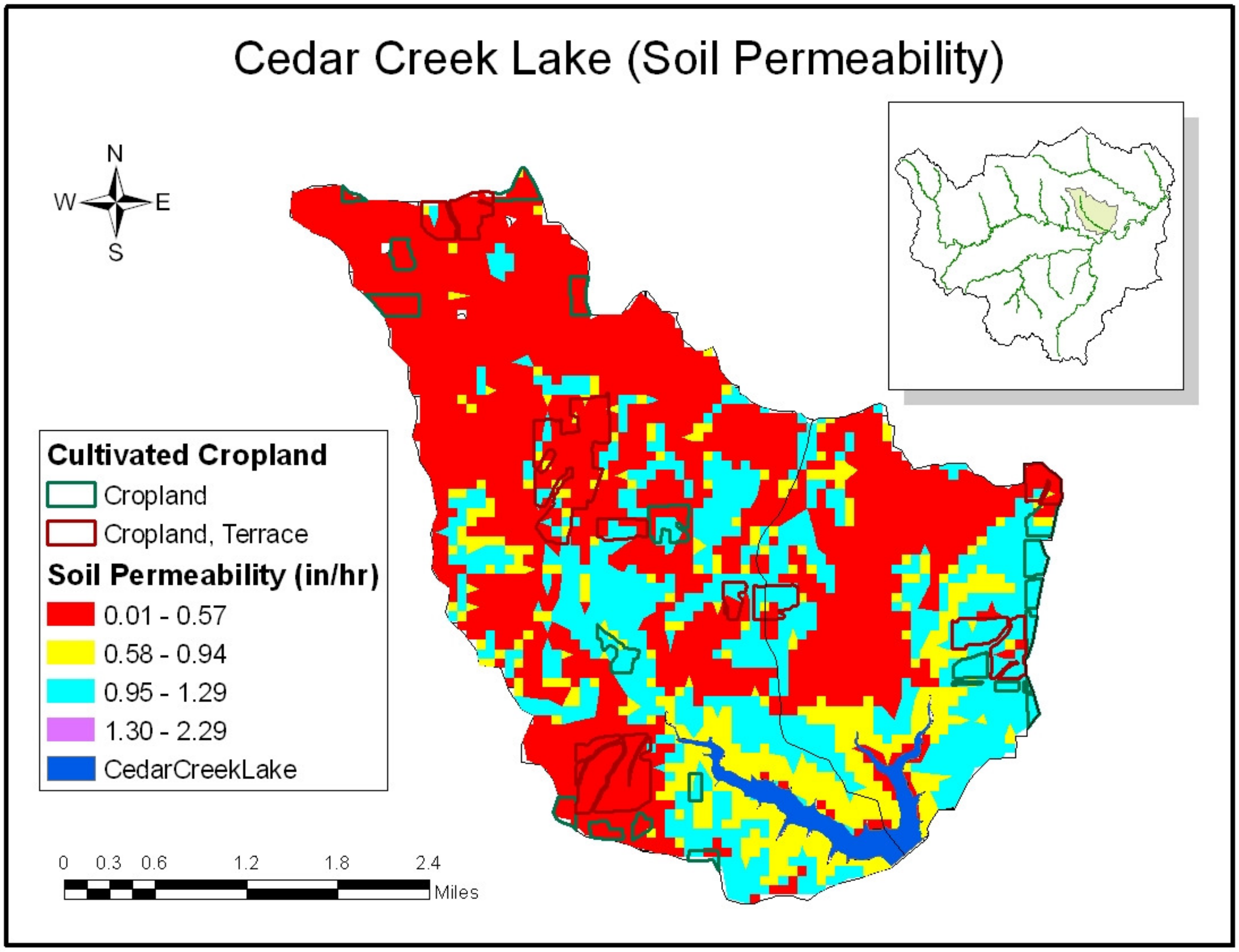

Figure 11. Soil permeability of Cedar Creek Lake Watershed.

Background Levels: Approximately 6% of the watershed is woodland, which is distributed primarily along the lower parts of both Cedar and Muddy Creeks. There are few wooded areas in the headwater streams. Although nutrients released from leaf decomposition may be contributing to the nutrient loading from the lower-order streams, soil loss, accompanied by nutrients, from the headwaters' streambank may also enter the lake. Cedar Creek Lake is a deep lake (>15 m). Because of its unique morphology, the main basin area (Site C3) of the lake is not well mixed and stratifies at about 3-4 meters for both temperature and dissolved oxygen (DO) throughout the summer (Lake Fort Scott Study Committee, 2006). A DO concentration of zero consistently occurs below 4 meters and low temperature (6˚C) typically appears below 6 meters. The prolonged DO stratification implies that internal nutrients released from the sediment may be another important nutrient source. According to the committee study report, the water samples collected from the bottom water column (50 m) had higher nutrient concentrations than those collected in the upper column (0.30 m) at the Site C3. For Example, on 8/2/2004, TP and reactive P concentrations were 2.06 mg/L and 1.60 mg/L at the bottom as opposed to 0.04 mg/L and 0.03 mg/L at the surface, respectively.

4. ALLOCATION OF POLLUTANT REDUCTION RESPONSIBILITY

The watershed model used for this TMDL analysis was Annualized AGricultural Non-Point Source Pollution Model (AnnAGNPS). AnnAGNPS is a batch-process, continuous-simulation, watershed-scale model specifically designed for agriculturally dominated watersheds (Bosch et al., 1998). The model does distributed-modeling, where a target watershed is subdivided into homogenous cells (hydrologic unit) to quantitatively estimate runoff, sediment, and nutrient loading. Earlier versions of this model (e.g., AGNPS), which are event-related models, have been broadly and successfully used in the central United States (e.g., Mankin and Kalita, 2000; Mankin and Koelliker, 2001). AnnAGNPS expands the original modeling capabilities of AGNPS by incorporating the Revised Universal Soil Loss Equation (RUSLE) and the Hydrogeomorphic Universal Soil Loss Equation (HUSLE) to predict soil and sediment leaving from the field.

In order to characterize the existing stream network and local land use/land cover information, various critical source area (CSA) and minimum source channel length (MSCL) were chosen, with the main CSA and MSCL being 5 ha and 50 m, respectively, for the Cedar Creek Lake Watershed. While the CSA is the threshold (minimum) upstream drainage area that defines a permanent channel, the MSCL is the minimum acceptable length for a source channel to exist. As these two parameter values are decreased, the drainage density of the network increases. Based on the CSA and MSCL settings, 1071 AnnAGNPS cells (or subwatersheds) and 506 reaches were generated and used in the watershed modeling (**Figure 12**). Prior to this watershed delineation, the high resolution National Hydrography Dataset (NHE) was used to determine the watershed's Digital Elevation Model (DEM). Several detailed model settings are shown in **Appendix A**.

The Cedar Creek Lake Watershed is a subwatershed of the Marmaton River Basin, and Marmaton's AnnAGNPS model had been previously calibrated and validated for stream runoff from three USGS gaging stations [Marmaton River near Fort Scott (06917500), Marmaton (06917380), and Uniontown (06917240)] using a Web-based Hydrograph Analysis Tool (Purdue University, 2007). Thus, the same hydrologic calibrated model settings were applied to the Cedar Creek Lake Watershed model and the weather data used in the model was the 2000 – 2005 Fort Scott data from the National Climatic Data Center. **Table 3** shows hydrologic simulation results of calibration and validation runs for the Marmaton River Basin. As indicated in the table, the Nash-Sutcliffe (NSF) index value, widely used for assessing the goodness of fit of hydrologic models, reveals that the annual results of model calibration and validation were within the recommended criteria rating from satisfactory (0.5 – 0.65) to very good (>0.75) (Moriasi et al., 2007). Results of AnnAGNPS modeling indicate that annual runoff averages 4,751 ac-ft during the period from 2000 to 2005. Average total streamflow (baseflow and runoff) for the entire watershed during the same period is 6,787 ac-ft.

Table 3. Model performance for hydrologic measure during 2000 – 2005.

Watershed	Area (sq. miles)	Runoff (%)	Simulation	NSF (monthly)	NSF (Annual)
Fort Scott	410	72	calibration	0.56	0.83
Marmaton	208	73	validation	0.50	0.81
Uniontown[1]	84	64	validation	0.38	0.64

[1]*Model simulation period = 2002 – 2005.*

For sediment [estimated by total suspended solids (TSS)] and nutrients, both were calibrated from the water quality data collected at two sampling sites on Cedar and Muddy Creeks in 1992 (**Table 4**). The results of the 6-year model simulation (2000 – 2005) indicate that annual runoff TN loads to the Cedar Creek and Muddy Creek arms of the lake are 4,947 kg (10,883 lbs) and 1,951 kg (4,292 lbs) while annual runoff TP loads are 741 kg (1,630 lbs) and 219 kg (482 lbs), respectively. The Cedar Creek arm receives an annual runoff sediment load of 507 metric tons whereas 196 metric tons of sediment enters the Muddy Creek arm each year (**Table 5**). Under baseflow conditions, sediment, TN, and TP concentrations are 5 mg/L, 0.37 mg/L, and 0.03 mg/L, respectively, based on reference values of Central Irregular Plain Ecoregion (Dodds et al., 2007). Therefore, annual baseflow sediment, TN, and TP loading to the lake are 13 metric tons, 929 kg (2,044 lbs) and 78 kg (171 lbs), respectively. The total watershed sediment and nutrient loadings are shown in **Table 6**.

Table 4. Characteristics of runoff water quality samples in 1992.

Sampling Date	Cedar Creek				Muddy Creek			
	TSS[1] mg/L	Nitrate-N mg/L	Ammonia-N mg/L	TP mg/L	TSS[1] mg/L	Nitrate-N mg/L	Ammonia-N mg/L	TP mg/L
4/13/1992	3	0.10	0.05	0.05	12	0.03	0.05	0.05
4/16/1992	16	0.18	0.05	0.05	29	0.34	0.05	0.11
4/19/1992	56	0.61	0.05	0.09	104	0.89	1.14	0.49
4/20/1992	27	--	0.05	0.10	167	0.71	0.10	0.49

[1]TSS abbreviated for Total Suspended Solids.

Table 5. Annual runoff sediment and nutrient loadings estimated by AnnAGNPS model.

Cedar Creek Lake	Runoff ac-ft/yr	Sediment metric tons/yr	TN kg/yr	Dissolved N kg/yr	TP kg/yr	Dissolved P kg/yr
Cedar Creek Arm						
Cedar Creek	3,386	498	4,685	2,858	719	208
Muddy Creek Arm						
Muddy Creek	1,161	196	1,456	919	206	61
Un-Named Trib.	206	9	311	293	8	3
Watershed, Total	***4,753***	***703***	***6,452***	***4,070***	***933***	***272***

Table 6. Annual total sediment and nutrient loadings.

Cedar Creek Lake	Flow ac-ft/yr	Sediment metric tons/yr	TN kg/yr	TP kg/yr
Baseflow	2,036	13	929	78
Runoff	4,753	703	6,452	932
Septic Systems	1	-	59	17
Total	***6,790***	***716***	***7,440***	***1,027***

For Cedar Creek Lake, the siltation/sedimentation rate is 8.8 ac-ft/yr, assuming that sediment capacity is 10% of the lake volume (4,400 ac-ft) with a designed life of 50 years. Using a bulk density of 35 lbs per cubic foot (Juracek, 2004), annual siltation rate at the current condition is 0.57 ac-ft. From 2002 to 2007, total sediment deposited in the lake is 3.45 ac-ft, which is about 1% of the sediment capacity.

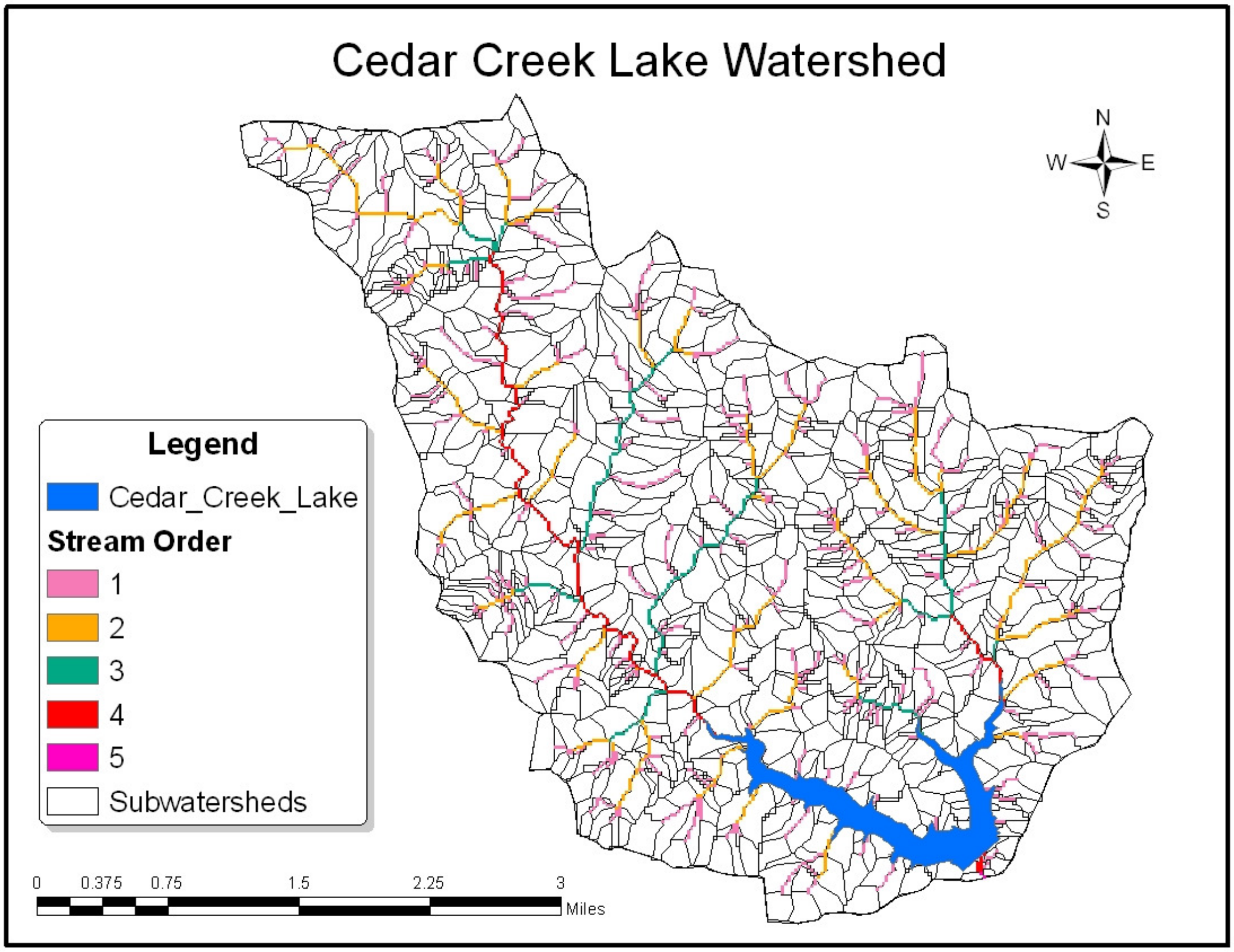

Figure 12. Subwatersheds (1071) and reaches (506) used in AnnAGNPS modeling.

Figure 13 shows runoff sediment load distribution and runoff TN and TP loads are shown in **Figures 14** and **15**, respectively. **Table 7** lists runoff sediment and nutrient loads of the existing land use and land cover groups and several management scenarios in the watershed. Converting all the LULC to the pasture condition, except for woodland and wildlife areas, annual sediment, TN and TP loads to Cedar Creek Lake are 450 metric tons (989,277 lbs), 1,779 kg (3,913 lbs), and 436 kg (960 lbs), respectively. The converted cropland contributes sediment, TN and TP are 13 metric tons, 87 kg (192 lbs), and 25 kg (56 lbs) respectively while the terraced cropland, that is converted to pasture, contributes 43 metric tons of sediment, 344 kg (758 lbs) of TN, and 88 kg (193 lbs) of TP.

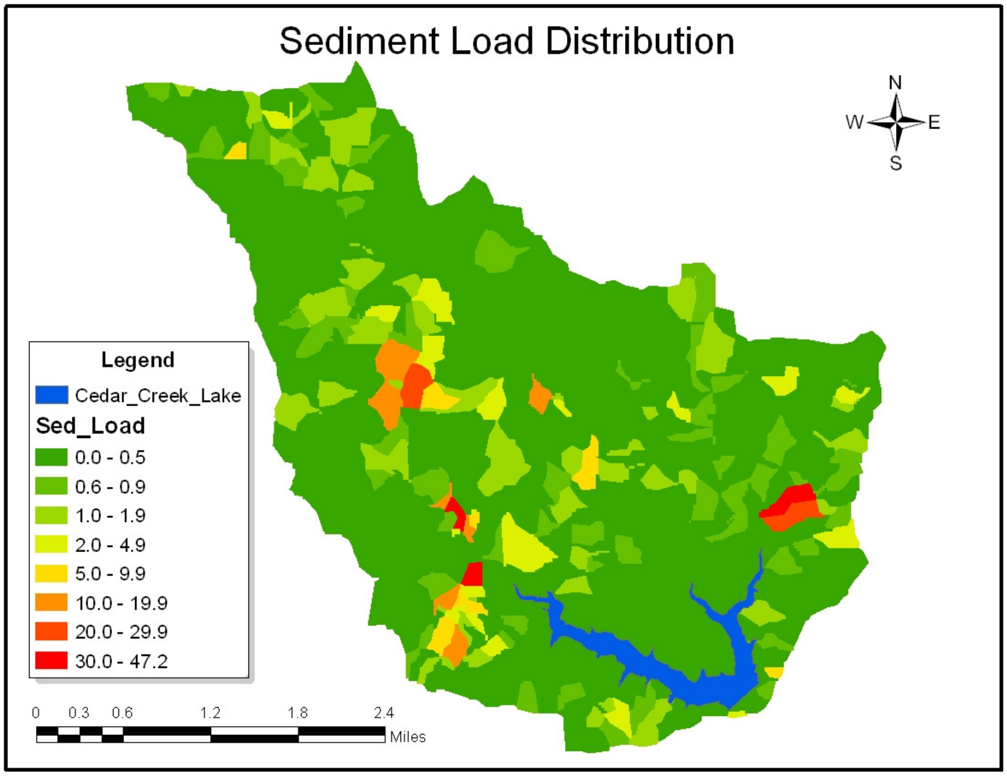

Figure 13. Annual runoff sediment load distribution (tons/yr).

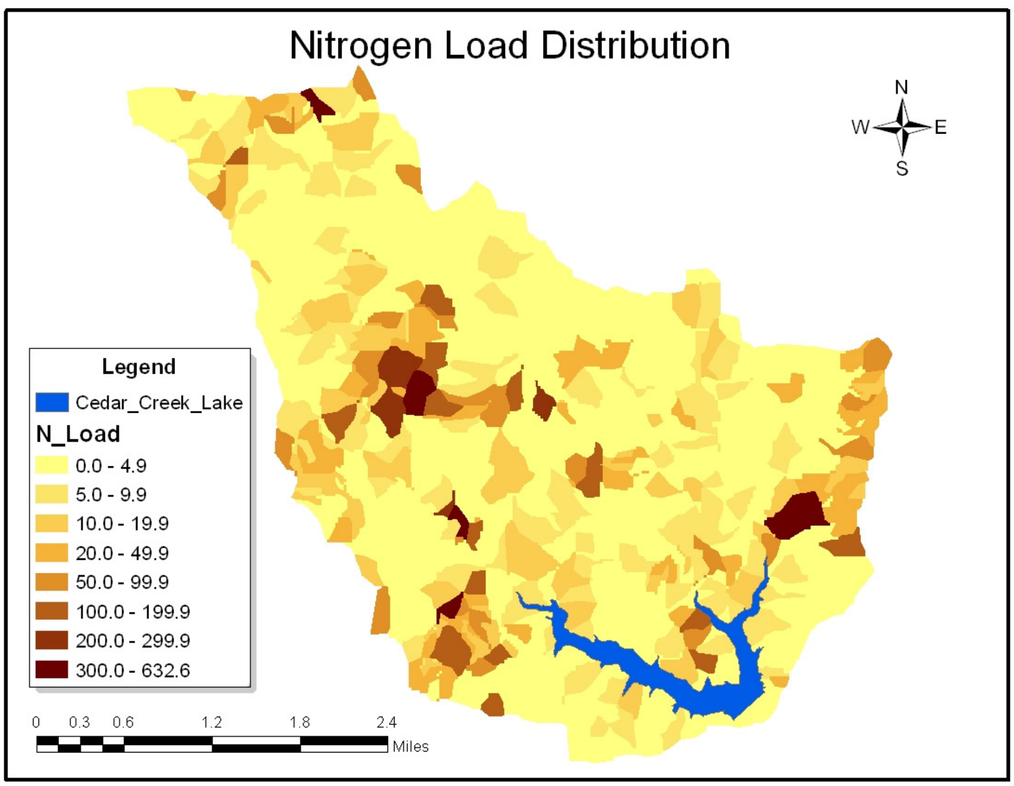

Figure 14. Annual runoff nitrogen load distribution (lbs/yr).

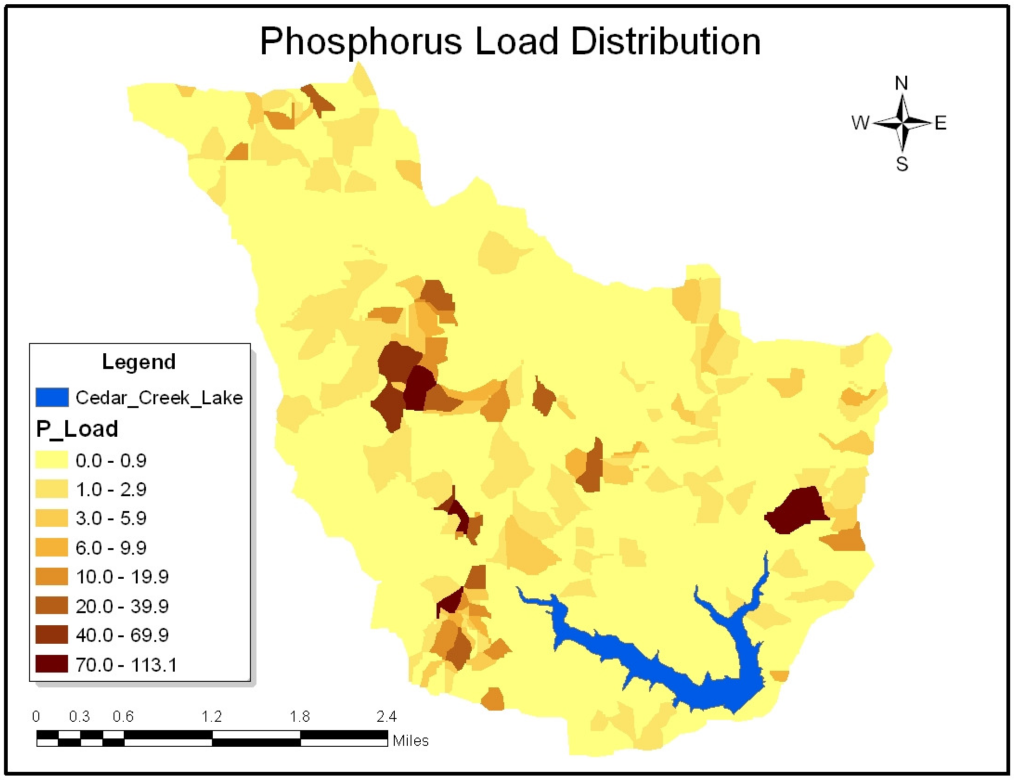

Figure 15. Annual runoff phosphorus load distribution (lbs/yr).

Table 7. Summary of AnnAGNPS-simulated runoff nutrient loads on an annual basis.

LULC	Modeling area	Current			All cropland terraced			All terraces removed		
		Sediment	TN	TP	Sediment	TN	TP	Sediment	TN	TP
	acre	m. tons/yr	kg/yr	kg/yr	m. tons/yr	kg/yr	kg/yr	m. tons/yr	kg/yr	kg/yr
Cropland										
Terraces	730	**299**	**2,869**	**521**	**299**	**2,869**	**521**	**332**	**4,054**	**573**
Non-Terraces	278	**136**	**1,315**	**196**	**134**	**1,266**	**204**	**136**	**1,315**	**196**
Pasture	4,501	153	706	132	153	706	132	153	706	132
Grazed Rangeland	515	6	864	9	6	864	9	6	864	9
Other										
Native Hay	523	4	72	6	4	72	6	4	72	6
Road Ways	6	11	24	4	11	24	4	11	24	4
Tame Hay	288	8	86	6	7	86	6	7	86	6
Urban	107	86	359	47	86	359	47	86	359	47
Water	182	-	-	-	-	-	-	-	-	-
Wildlife	733	0.010	134	8	0.010	134	8	0.010	134	8
Woodland	385	0.004	23	3	0.004	23	3	0.004	23	3
	8,248	*703*	*6,452*	*932*	*700*	*6,403*	*940*	*735*	*7,637*	*984*

Cedar Creek Lake was segmented into seven sections that include riverine, transitional, and main basin areas, according to lake morphological characteristics, but only the Lower Cedar Creek Arm (validation) and Main Basin (Calibration) areas were modeled using BATHTUB (**Figure 16**). Atmospheric N input data was obtained from National Atmospheric Deposition Program/National Trend Network while P deposition rate data was estimated using the 1983 study of Rast and Lee. Water quality data for the Main Basin segment was averaged using the 2004 – 2007 data while only 2004 data for the Lower Cedar Creek Arm. Watershed nutrient loading data was from the calibrated/validated AnnAGNPS model. The BATHTUB setting and nutrient model selections are provided in **Appendix B**.

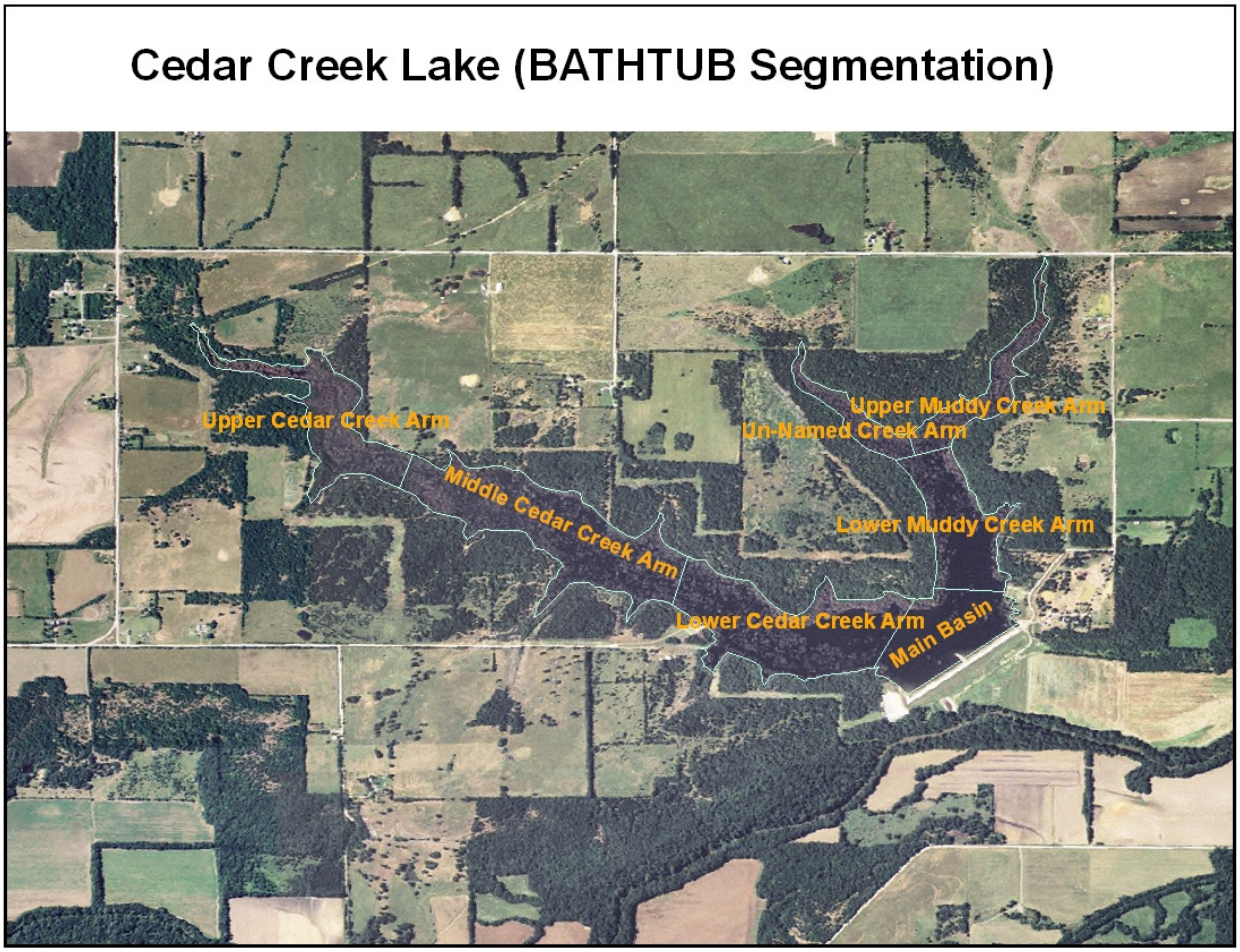

Figure 16. BATHTUB segments (riverine, transitional, and main basin areas).

Figure 17 shows the modeling results of calibrated and validated BATHTUB model. The simulated lake conditions typically correspond well with the observed condition for these two segmented areas, with the exception of Secchi depth values measured at Lower Cedar Creek Arm. A lack of Secchi depth readings in 2006 – 2007 was likely the main reason for this appearance of the exception. BATHTUB estimated that approximately 21% of TN (1,704 kg) and 70% of TP (730 kg) were retained annually by the lake.

Cedar Creek Lake is designated as a Class B Primary Contact Recreational Lake. According to Kansas eutrophication TMDLs (http://www.kdheks.gov/tmdl/eutro.htm), 12 µg/L of Chla is targeted for primary contact recreational lakes (i.e., swimming) whereas the 20 µg/L of Chla is implemented for secondary contact recreation lakes (i.e., fishing). However, with the public water supply use in the future, an ultimate target of average Chla concentrations of 10 µg/L should be attained.

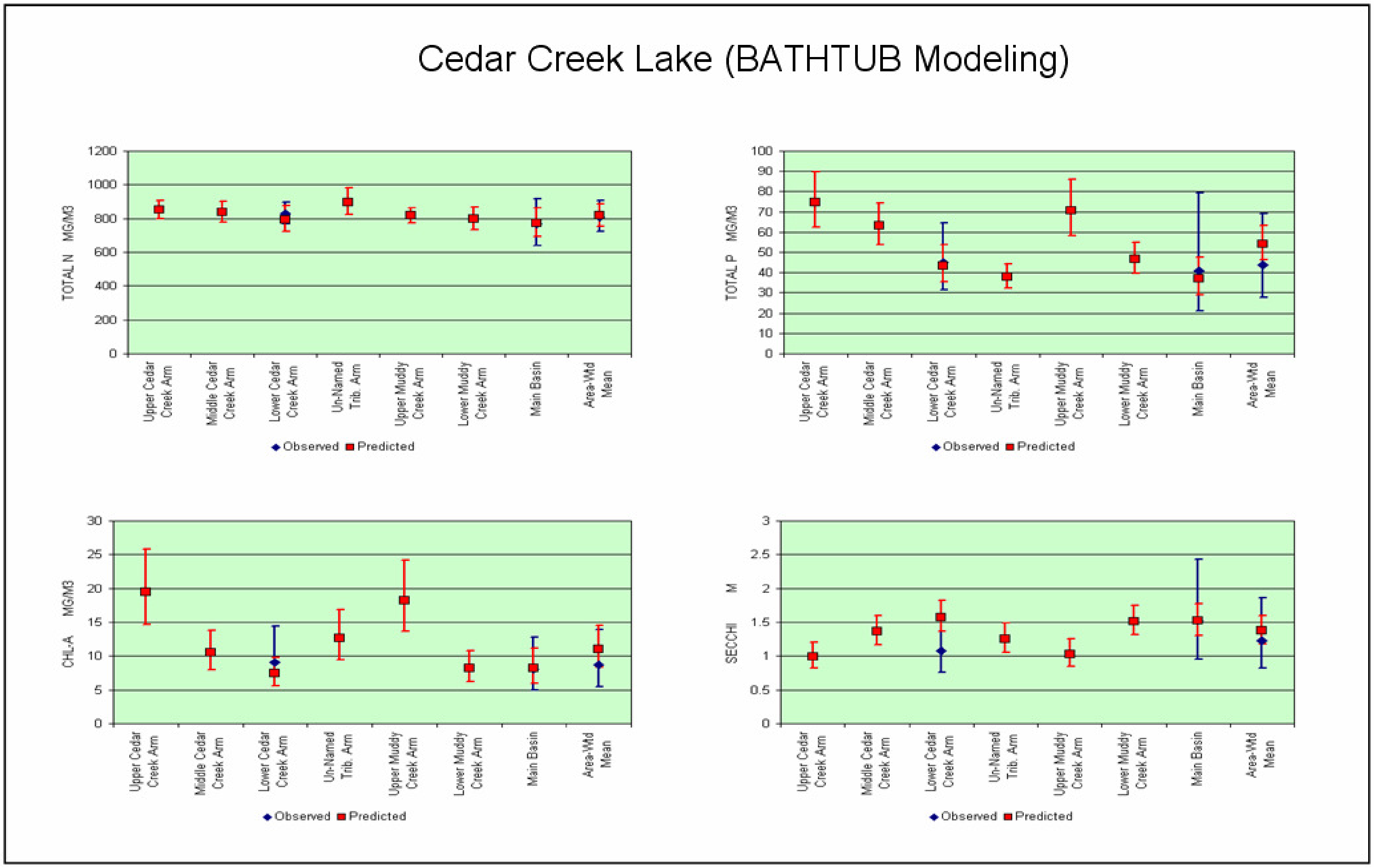

Figure 17. Error bar plots (mean $\pm$ standard deviation) of TN, TP, Chla, and Secchi depth parameters estimated by BATHTUB model.

Figure 18 shows several watershed management scenarios, including the existing (current), terraced cropland, non-terraced cropland (straight), and pasture conditions. As expected, the Chla level at Main Basin site is the highest for the non-terraced cropland management (8.6 µg/L) whereas under the pasture management the Chla level appears lowest (3.7 µg/L).

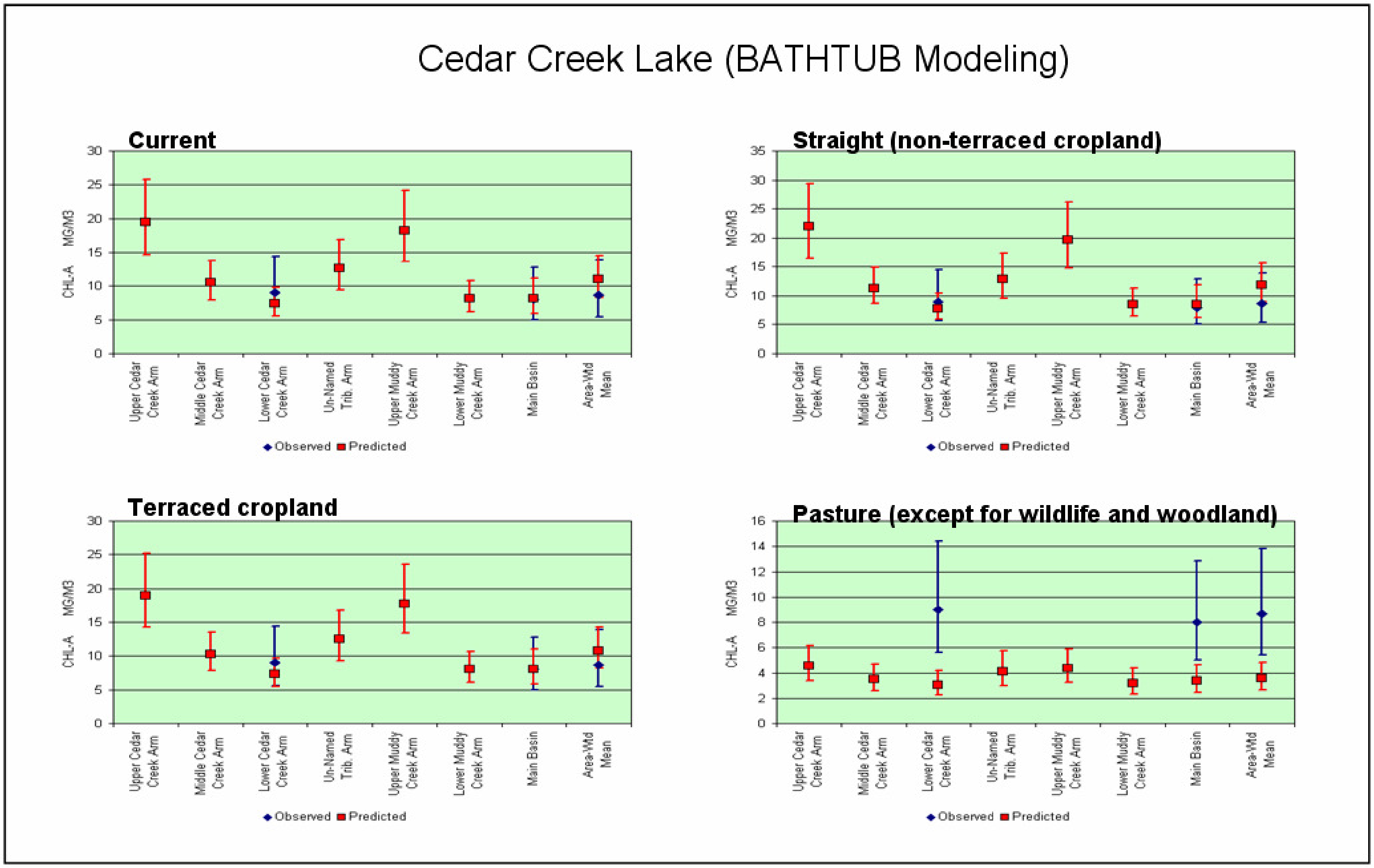

Figure 18. Error bar plots (mean + standard deviation) of Chla concentrations estimated by BATHTUB model for several watershed management scenarios.

The Chla level at the Main Basin site is below 10 µg/L, the ultimate TMDL target goal, even under the non-terraced cropland management. Impairments are likely to occur in the upper segments of Cedar Creek Lake. A Whole-Lake Management approach is recommended to ensure the maximum water quality protection for Cedar Creek Lake because this lake was just built in 2001 and is the youngest lake designated as the near-future drinking water source for Fort Scott City and surrounding communities.

Based on the modeling results, a 10% nutrient (TN and TP) reduction from the watershed is required to reach the endpoint for the whole lake area (**Figure 19**). Therefore, the total load capacity, including atmospheric deposition, to achieve 10 µg/L of Chla will be 7,352 kg/yr (16,173 lbs/yr) for TN and 933 (2,053 lbs/yr) for TP.

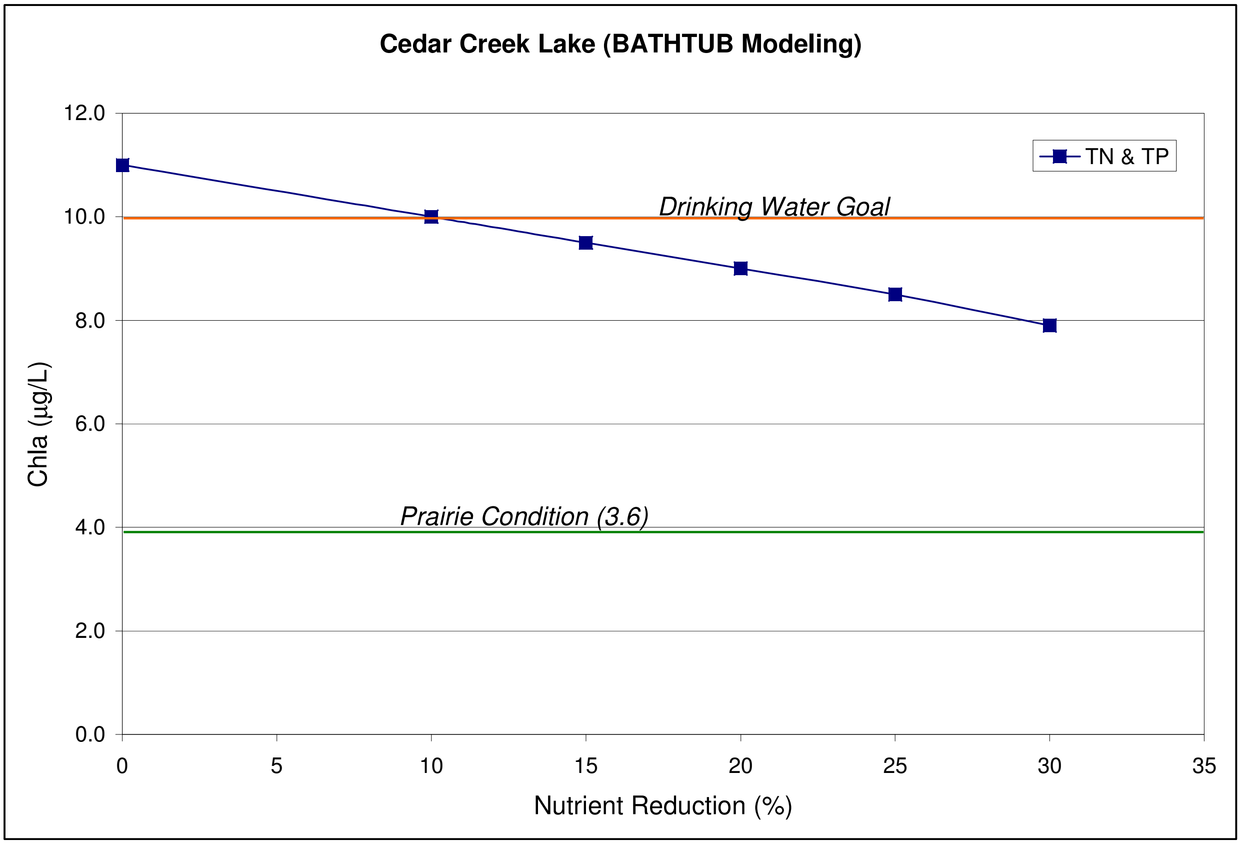

Figure 19. Changes in Chla levels in relation to nutrient loading reduction from the watershed.

Point Sources: There are no point sources in the watersheds. Although there are no NPDES facilities, Wasteload Allocation of the two CAFOs shall be also set to zero to protect Cedar Creek Lake's water quality.

Nonpoint Sources: The impairment is influenced by the septic tanks systems. According to NRCS Bourbon County Conservation District (personal comm., Schoenberger), the failing rate is about 50% for these on-site waste systems because of high clay content of the soils in the watershed. Assuming that typical average TN and TP concentrations are 50 mg/L and 14 mg/L, their annual TN and TP loads to the lake are 59 kg (130 lbs) and 17 kg (36 lbs), respectively. These point source nutrient loads account for approximately 0.8% of the overall TN and 1.6% of the TP from the watershed. Therefore, Load Allocations of these septic systems shall be set to zero to eliminate these source pollutions.

Nutrient loads from nonpoint pollution sources dictate lake Chla levels. The source assessment suggests that agricultural production, in particular cropland cultivation, directly contributes to increased Chla concentrations seen in the lake. Though Chla concentrations are generally low at Main Basin site, elevated concentrations (12 µg/L) above the public water supply target of 10 µg/L have been recorded. To manage Chla levels to the desirable endpoint, a 10% nutrient reduction from the watershed is suggested. Therefore, Load Allocations for the watershed are set to 6,695 kg/yr (14,729 lbs/yr) of TN and 924 (2,032 lbs/yr) of TP per year (**Table 8**).

Table 8. Nutrient allocations by pollution sources.

Cedar Creek Lake	TN kg/yr	TP kg/yr
Baseflow	836	70
Runoff	5,806	839
Septic Systems	53	15
Total	***6,695***	***924***

WRAPS Implementation Priority: Because this lake has slightly elevated Chla concentrations, it may be restored without extensive watershed management efforts so that its water supply function is fully supported. The Marmaton WRAPS should make this protection plan a **High Priority** for implementation.

Unified Watershed Assessment Priority Ranking: This watershed lies within the Marmaton River Basin (HUC 8: 10290104) with a priority ranking of 17 (High Priority for restoration work).

5. IMPLEMENTATION

Desired Implementation Activities

There is a good potential that agricultural best management practices will improve the water quality in Cedar Creek Lake. Some of the recommended agricultural practices are as follows:

1. Perform soil tests and apply nutrient best management practices (BMPs) to the critical/sensitive areas (**Figures 14 and 15**) to reduce excess nutrients to the lake,
2. Maintain conservation tillage and contour farming to minimize cropland erosion,
3. Promote and adopt continuous no-till cultivation to increase the amount of water infiltration and minimize cropland soil erosion and nutrient transports,
4. Install grass buffer strips along stream channels,
5. Reduce activities within riparian areas,
6. Control classic gullies located in the upper Muddy Creek Watershed,
7. Test septic systems in the watershed for proper maintenance and function,
8. Repair failing septic systems and promote proper maintenance.

Implementation Programs Guidance

Septic System Programs – LEPP

a. Promote proper maintenance of on-site wastewater treatment systems,

b. Locate failing on-site systems and provide technical assistance on appropriate replacements.

Nonpoint Source Pollution Technical Assistance - KDHE

a. Support Section 319 demonstration projects for reduction of sediment runoff from agricultural activities as well as nutrient management,

b. Provide technical assistance on practices geared to establishment of vegetative buffer strips,

c. Provide technical assistance on nutrient management in vicinity of streams,

d. support stream monitoring to establish a baseline of runoff water quality entering the lake and evaluate the effectiveness and efficiency of watershed management practices,
e. Incorporate the plan into the Marmaton Watershed Restoration and Protection Strategy (WRAPS).

Water Resource Cost Share Nonpoint Source Pollution Control Program - SCC
a. Apply conservation farming practices, including terraces and waterways, sediment control basins, and constructed wetlands,
b. Provide sediment control practices to minimize erosion and sediment and nutrient transport.
c. Coordinate implementation activities through the Marmaton WRAPS.

Riparian Protection Program - SCC
a. Establish or re-establish natural riparian systems, including vegetative filter strips and streambank vegetation,
b. Develop riparian restoration projects,

Buffer Initiative Program - SCC
a. Install grass buffer strips near streams,
b. Leverage Conservation Reserve Enhancement Program to hold riparian land out of production.

Extension Outreach and Technical Assistance - Kansas State University
a. Educate agricultural producers on sediment, nutrient, and pasture management,
b. Educate livestock producers on livestock waste management and manure applications and nutrient management planning,
c. Provide technical assistance on livestock waste management systems and nutrient management plans,
d. Provide technical assistance on buffer strip design and minimizing cropland runoff,
e. Encourage annual soil testing to determine capacity of field to hold nutrients.

Time Frame for Implementation: Pollutant reduction practices should be installed within the priority subwatersheds before 2012, with follow-up implementation, including other subwatersheds over 2012 – 2014.

Targeted Participants: Primary participants for implementation will be agricultural producers within the drainage of the lake.

Delivery Agents: The primary delivery agents for program participation will be the Bourbon County Conservation District for programs of the State Conservation Commission and the Natural Resources Conservation Service. Producer outreach and awareness will be delivered by Kansas State Extension and the Marmaton WRAPS. Implementation should be coordinated through the Marmaton WRAPS.

Funding: The State Water Plan Fund provides the primary funding mechanism for implementing water quality protection and pollution reduction activities in the state. Additionally, Marais des

Cygnes Basin has recently received $900,000 as a targeted watershed grant from EPA. This lake protection plan is a High Priority for WRAPS consideration.

6. MONITORING

Future lake sampling should occur three times between 2008 and 2014. Continuous water quality monitoring of tributary levels of nutrients will help direct abatement efforts toward major contributors. Additionally, tracking of the failing septic systems should be done to ascertain their nutrient contributions to the lake.

7. FEEDBACK

Discussion with Interest Groups: The staff of Bourbon County Conservation District of NRCS met to discuss the implications of this plan on October 17 – 18, 2007. The plan was discussed with the Leadership Team of the Marmaton WRAPS on **XX.**

Developed, January 10, 2008

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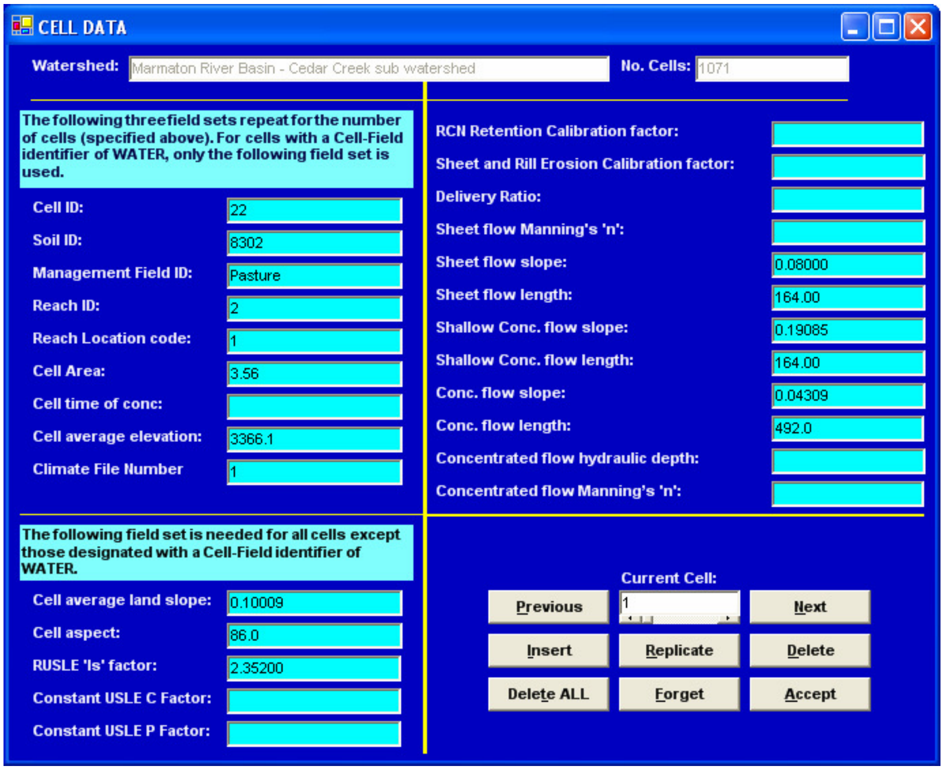
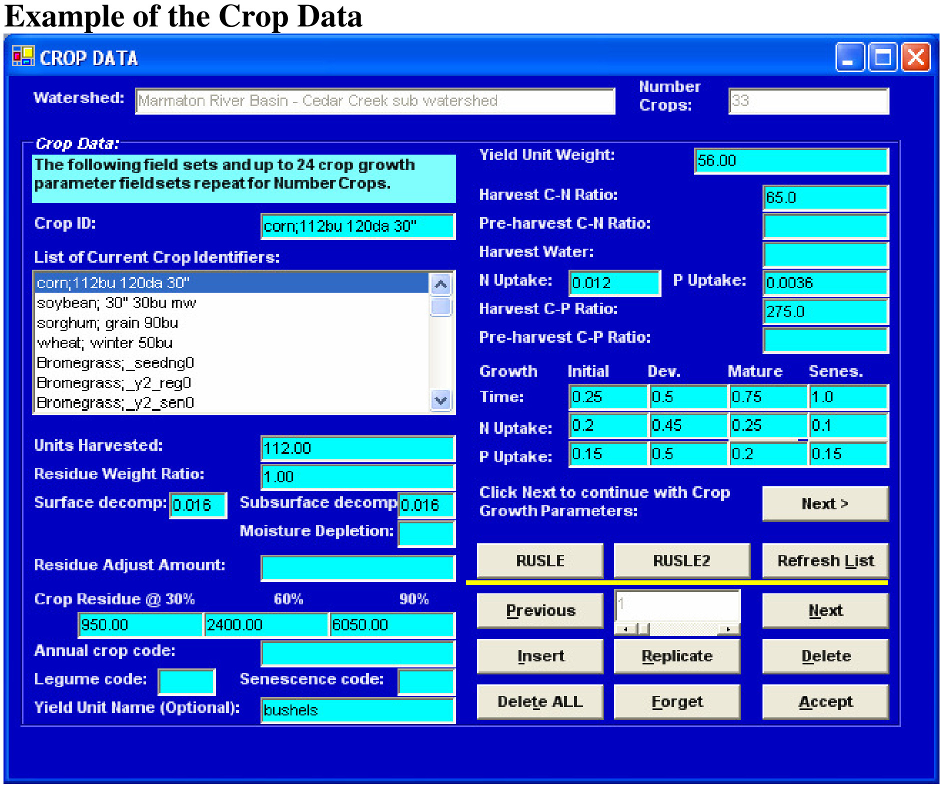
Appendix A. AnnAGNPS Input and Setting

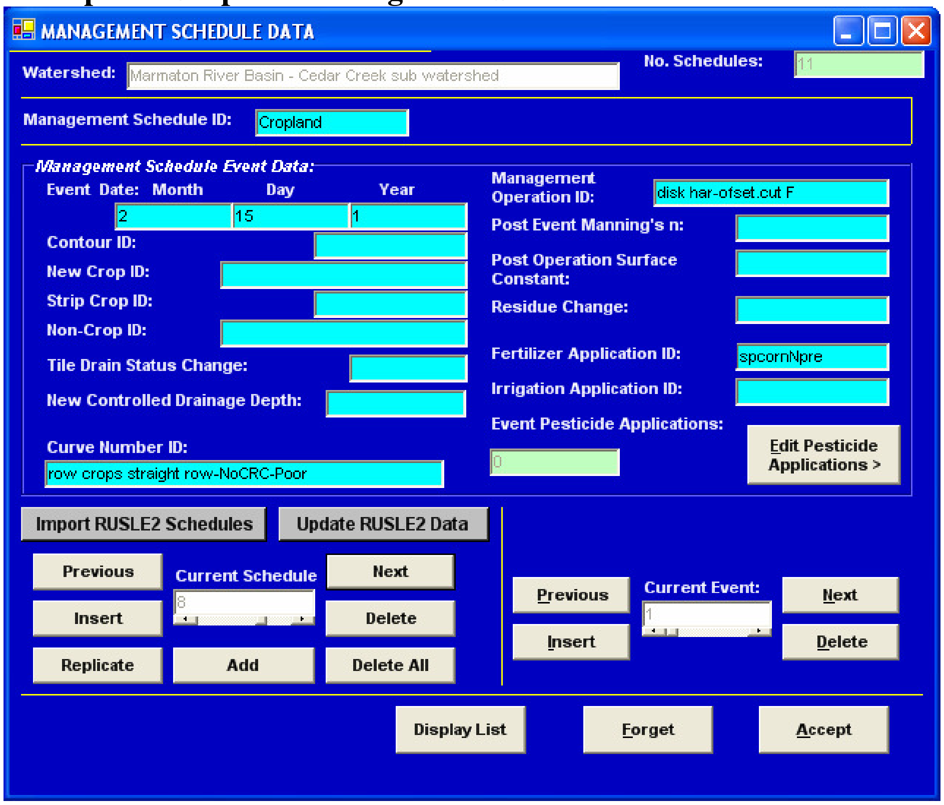
One of the 1071 Cell Data



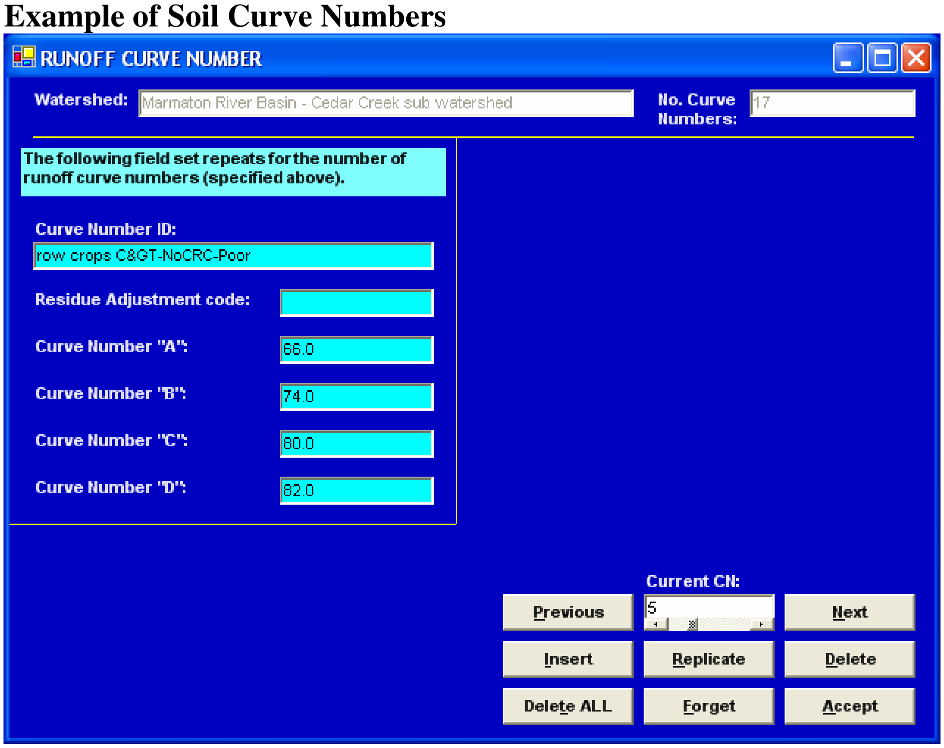
Example of the Crop Data



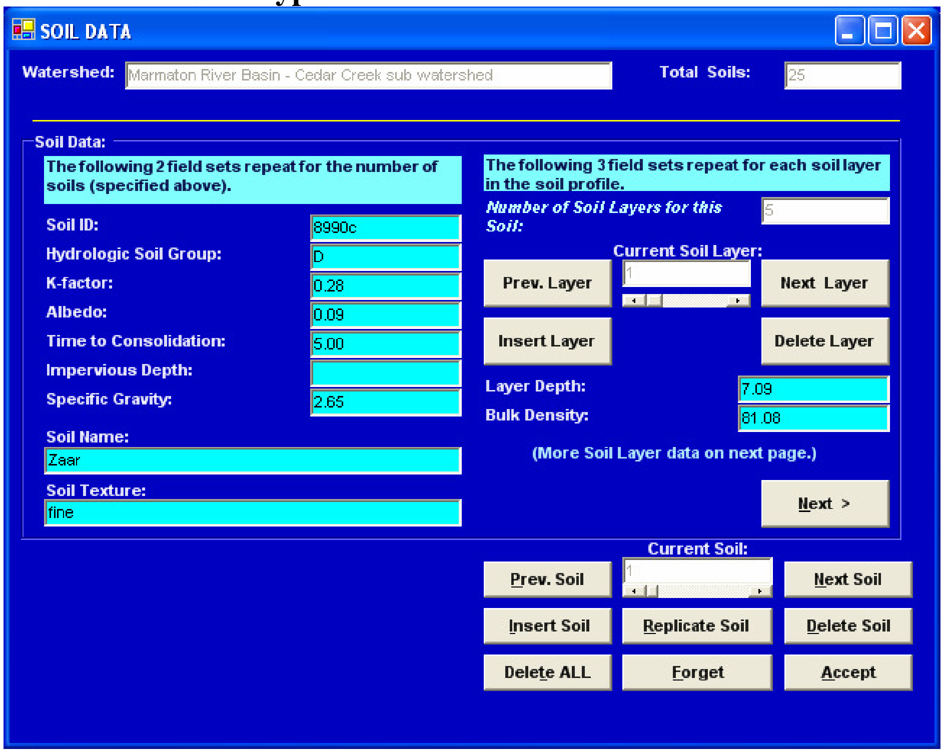
Example of Cropland Management Schedule



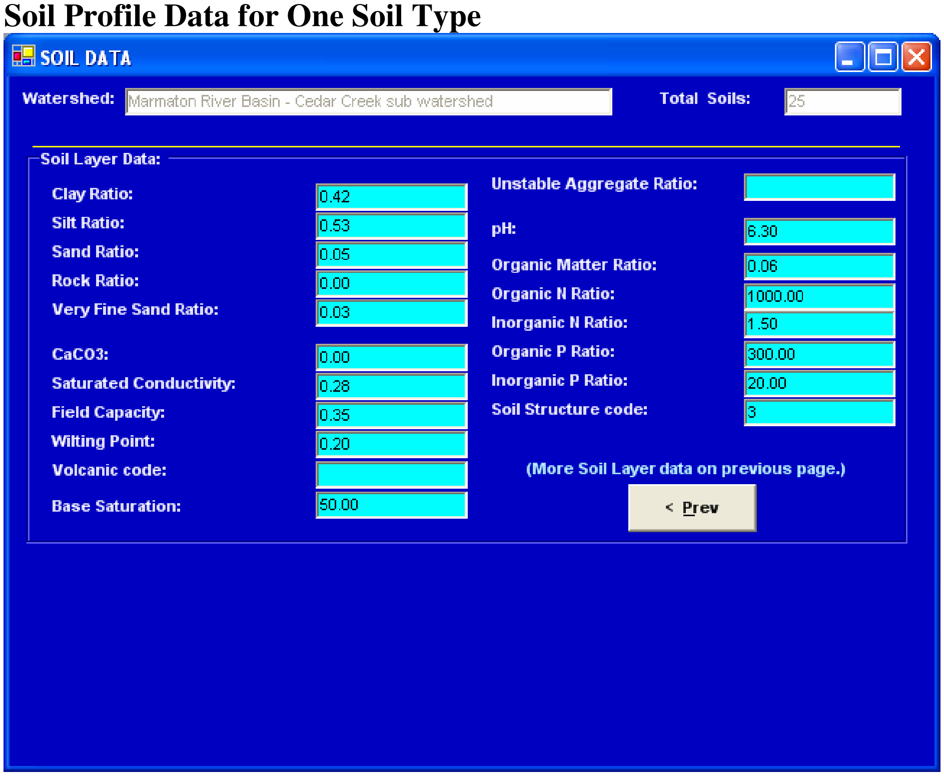
Example of Soil Curve Numbers



One of the 25 Soil Types

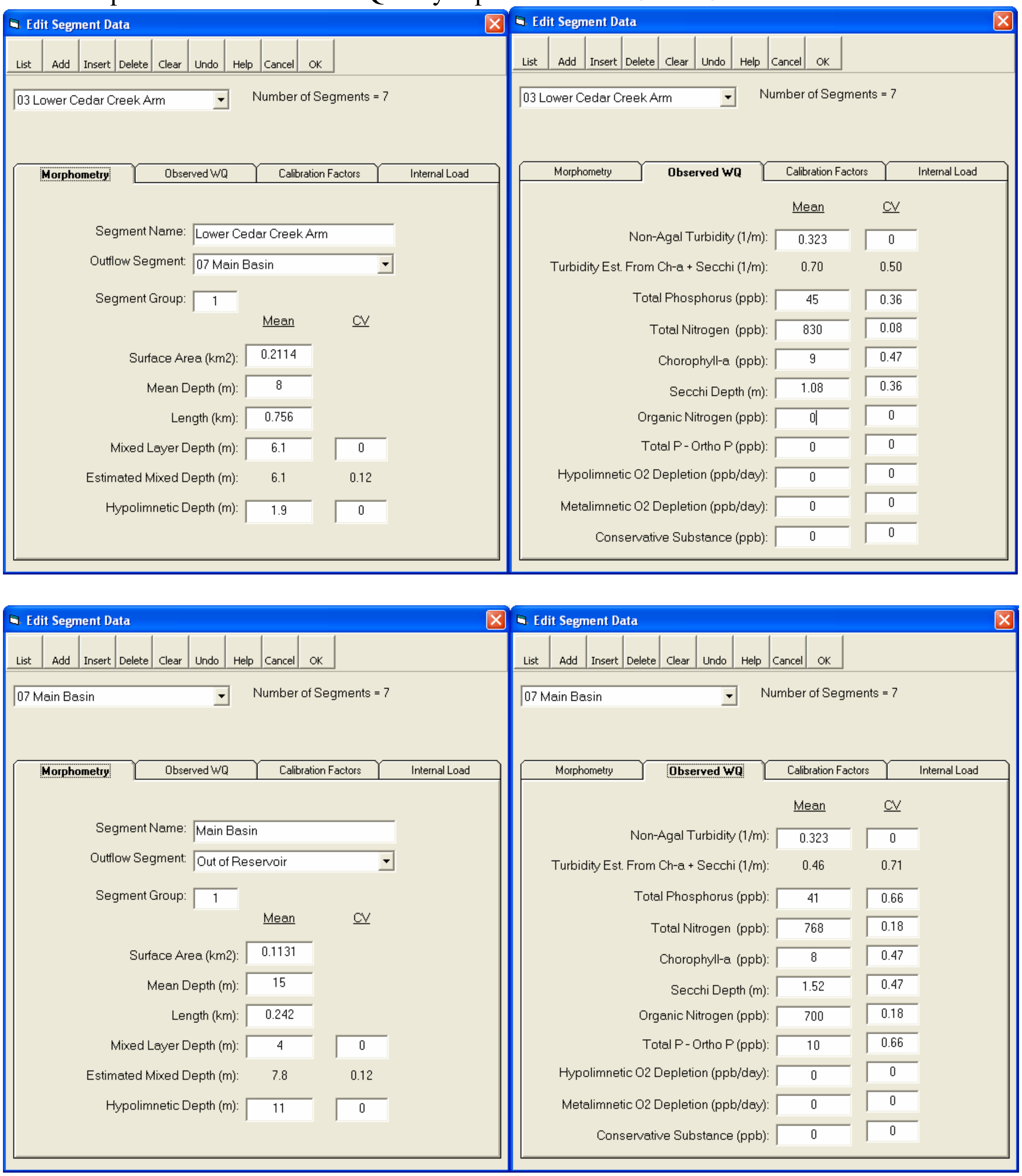


Soil Profile Data for One Soil Type

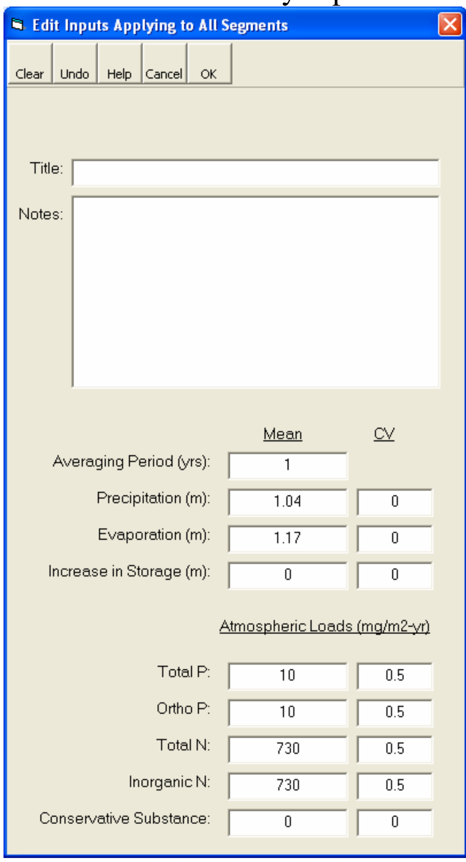


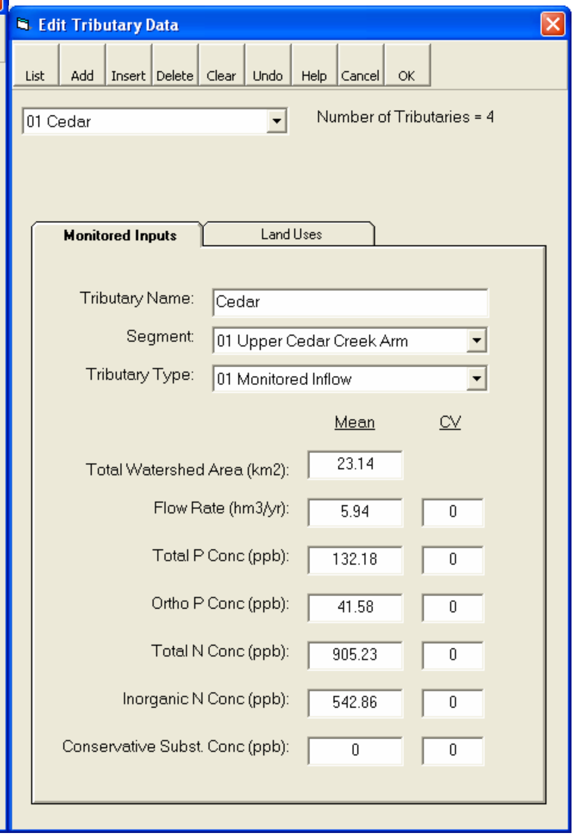
Appendix B. BATHTUB Input and Output Files

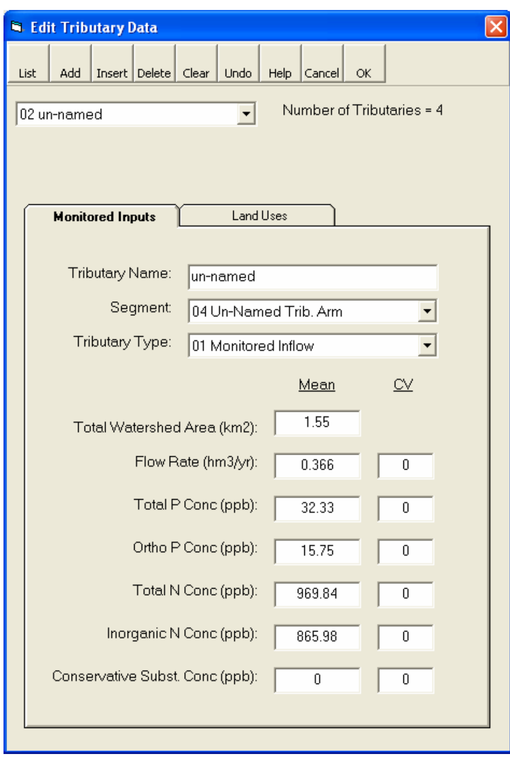
Lake Morphometrical and Water Quality Input for Lower Cedar Creek Arm and Main Basin

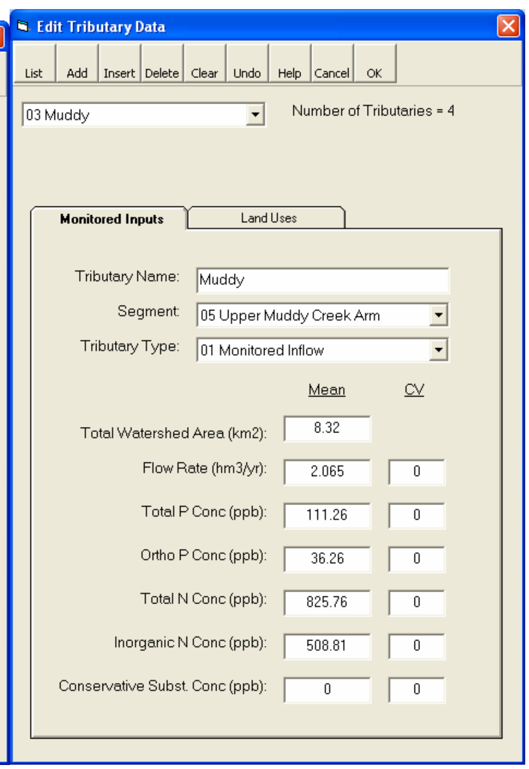


Climatic and Tributary Input

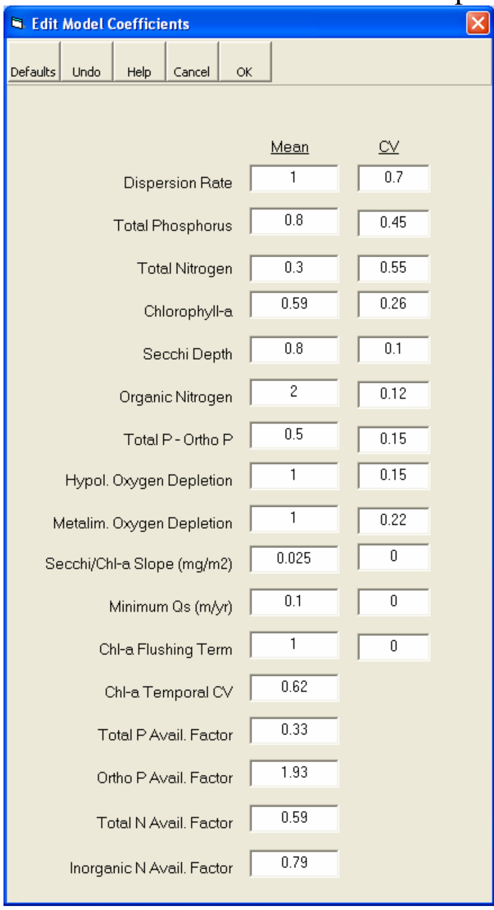


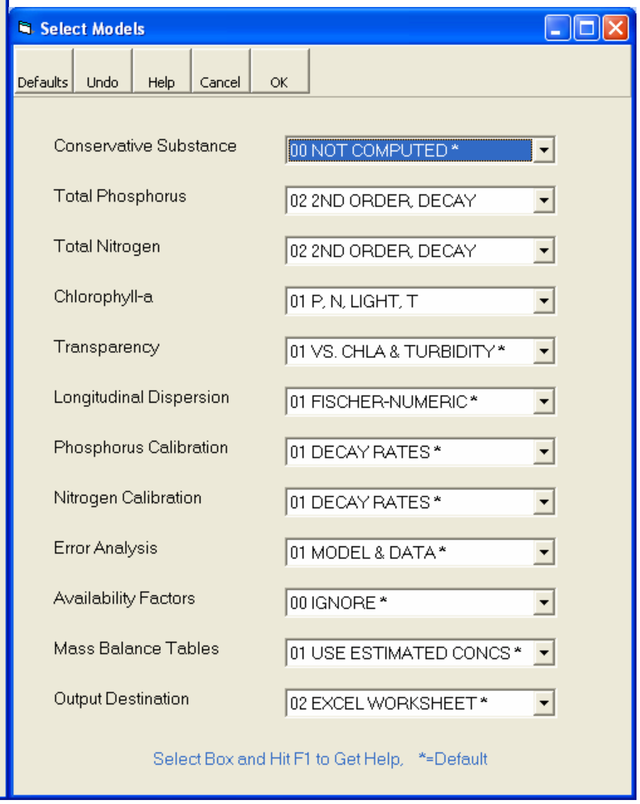




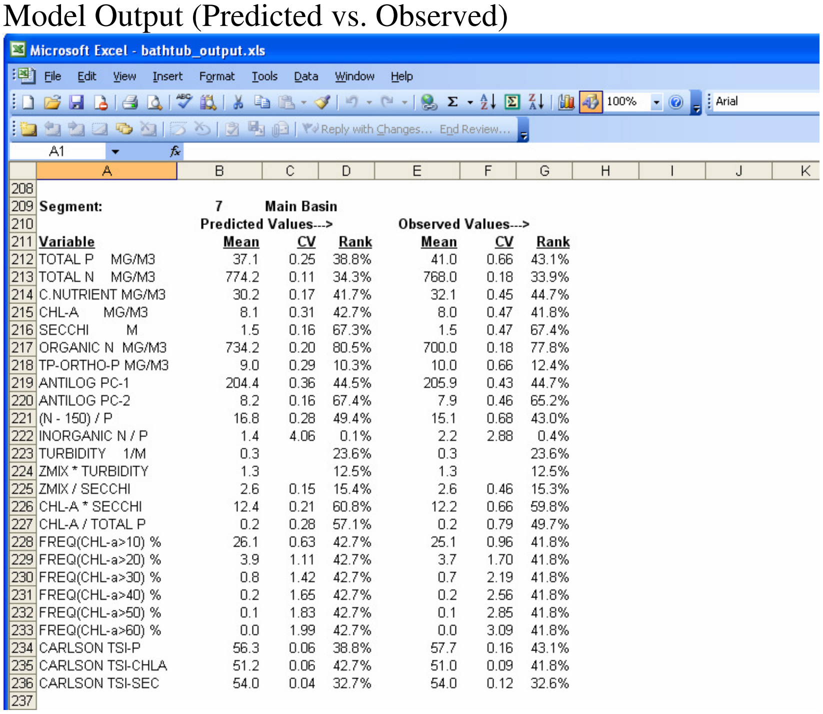


Model Selection and Coefficient Input





Model Output (Predicted vs. Observed)



	A	B	C	D	E	F	G
208							
209	**Segment:**	7	**Main Basin**				
210		**Predicted Values--->**			**Observed Values--->**		
211	**Variable**	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
212	TOTAL P MG/M3	37.1	0.25	38.8%	41.0	0.66	43.1%
213	TOTAL N MG/M3	774.2	0.11	34.3%	768.0	0.18	33.9%
214	C.NUTRIENT MG/M3	30.2	0.17	41.7%	32.1	0.45	44.7%
215	CHL-A MG/M3	8.1	0.31	42.7%	8.0	0.47	41.8%
216	SECCHI M	1.5	0.16	67.3%	1.5	0.47	67.4%
217	ORGANIC N MG/M3	734.2	0.20	80.5%	700.0	0.18	77.8%
218	TP-ORTHO-P MG/M3	9.0	0.29	10.3%	10.0	0.66	12.4%
219	ANTILOG PC-1	204.4	0.36	44.5%	205.9	0.43	44.7%
220	ANTILOG PC-2	8.2	0.16	67.4%	7.9	0.46	65.2%
221	(N - 150) / P	16.8	0.28	49.4%	15.1	0.68	43.0%
222	INORGANIC N / P	1.4	4.06	0.1%	2.2	2.88	0.4%
223	TURBIDITY 1/M	0.3		23.6%	0.3		23.6%
224	ZMIX * TURBIDITY	1.3		12.5%	1.3		12.5%
225	ZMIX / SECCHI	2.6	0.15	15.4%	2.6	0.46	15.3%
226	CHL-A * SECCHI	12.4	0.21	60.8%	12.2	0.66	59.8%
227	CHL-A / TOTAL P	0.2	0.28	57.1%	0.2	0.79	49.7%
228	FREQ(CHL-a>10) %	26.1	0.63	42.7%	25.1	0.96	41.8%
229	FREQ(CHL-a>20) %	3.9	1.11	42.7%	3.7	1.70	41.8%
230	FREQ(CHL-a>30) %	0.8	1.42	42.7%	0.7	2.19	41.8%
231	FREQ(CHL-a>40) %	0.2	1.65	42.7%	0.2	2.56	41.8%
232	FREQ(CHL-a>50) %	0.1	1.83	42.7%	0.1	2.85	41.8%
233	FREQ(CHL-a>60) %	0.0	1.99	42.7%	0.0	3.09	41.8%
234	CARLSON TSI-P	56.3	0.06	38.8%	57.7	0.16	43.1%
235	CARLSON TSI-CHLA	51.2	0.06	42.7%	51.0	0.09	41.8%
236	CARLSON TSI-SEC	54.0	0.04	32.7%	54.0	0.12	32.6%
237							